JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
SCHOOL OF HYDRAULIC AND WATER RESOURCES ENGINEERING
MASTERS OF SCIENCE PROGRAM IN HYDRAULIC ENGINEERING

Hydrologic analysis of storm water drainage system of Bure town under the effect of urban expansion.

A thesis Proposal submitted to the School of Graduate Studies of Jimma institute of technology in Partial fulfillment of the requirements for the Degree of Masters of Science in Hydraulic Engineering.

By: Mossie Adams

December,2017
Jimma, Ethiopia

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Main Advisor: Dr. Dejene Beyene (PHD)
Co-Advisor: Mr. Wakjira Takala (PhD Candidate)

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Approval

Abstract

Bure town is one of the rapidly growing city found in Amhara Region where storm water management is getting in to a great challenge affecting the environment and the community at large. As the result of urbanization expansion and increasing surface impermeability, uncontrolled flooding from the storm water drainage system has resulted in damage of the small drainage channels, blockage of channels, deterioration of roads and land degradation. The aim of this study is hydrologic analysis of storm water drainage system of Bure town under the effect of urban expansion. Landsat imagery of 1986,2010 and 2017 for land use/land cover classification was performed based on the Satellite imageries. Geographical Information System software is used to prepare the classified maps and ground truth observations were also performed to check the accuracy of the classification. As the results of land use land cover three classes in 1986, 2010 and 2017 was performed how much stormwater runoff volume with in study area increase and decrease for different land use land cover from 1986 through to 2010 and 2017 of significant shifts from some classes to others was also observe. The Bure town bare land and built-up region is growing and it has affected the natural resources like water, agricultural and vegetation and impact of on the environment can be seen. In this study, Bentley civil Storm V8i dynamic storm water modeling was used to calculates and analyzes the hydraulic response of the drainage system through dependent systems of conduit, manhole and outlet to visualize flooding problems and identify the flood risk in the Bure town storm water drainage system. The results obtained from hydraulic condition for stormwater is the overcharged-flow street surface flooding from the catchment and manhole that computed peak discharge of drainage system.

The findings of this study indicated that the challenge stormwater management in Bure town respondents claimed that the lack of community awareness, shortage of disposing area, existing drains not well planned, flooding occurrences in the street, blockage of drainage system by the solid waste and lack of clearance stormwater drainage lines they have none functional services of the system.

Key word: *Arc Gis 10.4.1, Bentley Civil Storm V8i, Bure town, Stormwater drainage system, Stormwater management***.**

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Acronyms

AACRA	Addis Ababa City Road Authority
AASHTO	American Association of State Highway and Transportation Origination
BMP	Best Management Practices
CCS	Compression Convectional and Sustainability
CM	Catchments
CCUVA	Climate Change and Urban Vulnerability in Africa
CO	Conduit
CSM	Conventional Stormwater Management
CUM	Cube Meter
DEM	Digital Elevation Model
ERA	Ethiopian Roads Authority
EEA	European Environmental Agency
EPA	Environmental Protection Agency
FDROECSA	Federal Democratic Republic of Ethiopia Central Statistical Agency
FHWA	Federal Highway Administration
FUPCOB	Federal Urban Planning Coordinating Bureau
GIS	Geographic Information System
HGL	Hydraulic Grade Line
IDF	Intensity-Duration-Frequency
LULC	land use land cover
MH-	Manhole
NUPI	National Urban Planning Institute
O	Outfall
OPW	Organization Program Warning
USGS	United States Geological Survey
USDA	Urban Storm Drainage Assessment
USWD	Urban Storm Water Drain
SSM	Sustainable Stormwater Management
SWDM	Storm Water Drainage Management
SWM	Storm Water Management

CHAPTER ONE

INTRODUCTION

1.1. Background

Urbanization is one of the most important demographic trends of the twenty-first century. The majority of the population growth is concentrated in towns and cities. In the developing countries, most the urban growth is unplanned, leading to rapid densification, and associated construction of buildings resulting in dramatic increase in impermeable areas due to paving and built-up areas. As population grows, demand for housing and commercial amenities naturally follows and also urbanization adds roads, rooftops, parking lots, sidewalks, and other imperviousness to the landscape management (Moglen, 2007).

Transformation of rural lands into urban area increases a watershed's response to precipitation large amounts of pervious land use have been replaced by impervious land use and a network of man-made drainage has altered the natural drainage characteristics. Consequently, the impact of land-use changes in urbanization has caused an increase in erosion and the discharge volume of storm runoff and a decrease in time of concentration in a watershed (USDA, 1986). Storm water discharges are produced when the capacity of the land to retain precipitation is exceeded and run-off occurs. Run-off will be influenced by rain fall and intensity (millimeter of rain fall per hour) and duration, antecedent storms and a number of watersheds, and land use characteristics such as slope, soil type, and impervious surfaces in (AASHTO, 1991).

Urban stormwater modeling is important for constantly increasing three global trends: Urbanization, Population growth, and Climate change. In the world has induce a rapid growth of cities, making stormwater management ever more challenging while at the same time a rising number of people will affect by the harmful effects of stormwater on the environment. In many areas, these effects are expected to be amplified in the future due to climate change and associated higher frequencies of extreme weather event (EEA, 2001).

In Ethiopian context the watersheds of many urban area receive significant amount of annual rainfall and where rainfall intensity is produced high, Control of runoff at the source, flood protection, and safe disposal of the excess water/runoff through proper drainage facilities becomes significant (FUPCoB, 2008).

Amhara region town are concerned with storm water leading into floods especially during the rainy season due to lack of integration road and drainage infrastructure in contribution for impact of urban flood on urban infrastructures (Moges, 2008).
Drainage problems with in Bure town impermeability increases with the increase in impervious surfaces (residential houses, commercial buildings, paved roads, parking lots), and drainage pattern changes, overland flow gets faster which leads flooding and environmental problems. It is a crucial problem facing the existing and future road and other infrastructure (Bure municipality, 2014). Thus, there is a need of studying the stormwater management in Bure town in order to model the required improvements in the drainage system consequently, decrease the risk of flooding and produce a safe environment.

1.2. Statement of the problem

The process of urbanization not only destroys the vegetation cover, but also alters the natural course of water flow. The increase in urbanization leads to the construction of more roads, sidewalks, and buildings. This results in reducing natural permeable surface that can infiltrate water into the ground. As a result, the impermeable surface will create flooding and more storm water runoff for the town (Pazwash, 2011).
Lack of urban Storm water drainage (USWD) management represent one of the most common sources of compliant from the residents in many urban centers of Amhara region, and this problem gets worse and worse with the rate of urbanization. Due to increased densification and impermeability of the urban landscape, the planning as well as implementation of storm water protecting structures is insufficient (Kefyalew, 2004).
Storm drainage systems of a town are ideally aimed to handle peak flow resulting from rainfall of return period equal or greater to their design year. Flooding due to intensive rainfall, this may be due to either small drainage channel, an incremental of rainfall, inadequate drainage management and, lack of a reliable garbage collection and disposal, lack of street cleaning, lack of control in construction sites, non-existence of drainage master plan and lack of efficient and effective maintenance of drainage scheme in Bure town.

1.3. Objectives of the Study

1.3.1. General objective

The overall goal of this study to solve stormwater drainage problems of Bure town under the effect of urban expansion.

1.3.2. Specific objectives

1. To evaluate the impact of land use land cover change on storm water runoff with in the study area
2. To assess the flood impact of storm water drainage systems using Bentley Civil Storm
3. To identify the major challenges in urban storm water drainage management system.

1.4. Research Questions

1. Does the impact of land use land cover changes on storm water runoff with in study area?
2. What is flood impact of storm water drainage systems in Bure town?
3. What are the major challenges in managing the drainage system in the study area**?**

1.5. Scope of the study

Total area of urban catchments is 1240Ha, but the study area is 668Ha to be analysis for flooding impact of storm water drainage system to be used because the remaining area does not affect drainage problems (Bure municipality, 2010). This research also does not include assessment of all types of drainage structures except proposing Manhole, conduit and outlet type and size of required drainage structures. In this research investigation of surface water drainage is included but Sub – face drainage, wastewater and water quality is not included.

1.6. Significance of the research

The investigation of storm water drainage problems in Bure town will contribute in solving the storm water drainage problems and sustain the drainage systems under urban expansion. It also helps to minimize the effect of possible damage as a result of storm water runoff on streets and on the surrounding environment. Because, the existing conventional drainage systems of Bure town are not managing the stormwater runoff passing through, resulting overflow.

To know problem of damage and preserve the structures by avoiding further deterioration for taking correct measures as well as to reduce problems and disturbance to travel due to over flow of water in the main road due to flooding.

Any stakeholder working in the area of urban storm water drainage infrastructures can use it as a reference for proper design, implementation and maintenance of urban road surface drainage. Managing urban storm water drainage systems has an important role for sustainable environmental management by keeping the service life of urban utility like road, houses, water supply lines and any urban infrastructures.

1.7. Study outline

This thesis is organized in to five chapters:

Chapter one: Outlines the statement of the problem, objectives of the study and research questions. The chapter also provides some background information on the problems of storm water drainage system in Bure town in addition to by expansion of urbanization and inadequate storm water drainage for the town.

Chapter two: Briefly reviews related literature about storm water drainage System this included related to storm water management in the Stormwater management in developing countries, conventional and sustainable storm water management, best management practices and also drainage system of flooding and causes of flooding in the urban area.

Chapter three: Deals with the location and general Bure town faces of the study areas and it outlines the research methodology employed in this study. The approaches used for this study are included and discussed.

Chapter four: Focusses on review, result and discussions using appropriate approaches of minimize or avoiding stormwater drainage problem and safe environment with in Bure town.

Chapter five: Summarizes the entire study by outlining a brief conclusion, and forwarding some recommendations.

1.8. Limitations

The limitation was problem of secondary data from Bure town municipality. There was no recorded data related with drainage system for scaled land use and land cover map of town and drainage network so that, this research have used Landsat satellite for overall drainage impact of storm water runoff but there is no land use map of town to compare it with the satellite map of land use.

CHAPTER TWO

LITERATURE REVIEW

2.1. General Overview

Storm water is any water resulting from rainfall or other precipitation that runoff surfaces or infiltrate into the ground during or after storm. The information on storm water runoff quantity is needed for planning, design and operation of urban drainage systems (Dagnachew, 2009).

A Stormwater drainage system receiving, conveying, and controlling discharges in response to precipitation and snowmelt. Such systems consist of ditches, culverts, swales, subsurface interceptor drains, roadways, curb and gutters, catch basins, manholes, pipes, detention ponds, and service lateral lines. An important social aspect is to maintain public health and safety; hence an efficient drainage of storm water and wastewater is essential to avoid impact of flooding on life and property. In addition, the current environmental awareness involves the protection of the receiving waters from the pollutants that may be dragged by water flowing in the surface during heavy rain events (Viessman *etal,* 2009).

Land surface is covered by buildings and pavement, do not allow rain soak into the ground. Instead, most developed areas rely on storm drains to carry large amounts of runoff from roofs and paved areas to nearby waterways. In heavily developed cities related impervious surfaces can constitute up to 70% of the total impervious urban area (Wongetal, 2000).

Bure town had significant problem, especially on the shortage of with exhausting services in integrating with road and drainage, waste water disposal, solid waste management and other infrastructures system has been critical disturbance where the system could not fully storm water management around the city of storm water drainage system.

2.2. Storm water management

Storm water management is an increasingly important consideration in the design of urban drainage systems. Storm water management practices, when properly selected, designed, and implemented, can be utilized to mitigate the adverse hydrologic and hydraulic impacts caused by drainage facilities, thereby protecting downstream areas from increased flooding, erosion, and water quality degradation. Existing downstream conveyance constraints, particularly in cases where the roadway drainage system (Schmitt, 1999).

2.2.1. Storm water management in developing countries

The increasing urbanization of the world's population is constantly creating new challenges for stormwater management. Although rain is vital for both human beings and their environment (to replenish rivers, water points and groundwater, grow vegetation), rainfall events generate flows and volumes of water that can be difficult to control and that accumulate in the lowest parts of towns, flooding residential areas and creating pools of stagnant water under the factors influencing stormwater management of town (Christophe, 2013).

A: Rainfall patterns (frequency and intensity of rainfall)

In the countries of east Africa, tropical or equatorial zones, precipitation is 3 to 4 times more intense than rainfall in temperate areas, thus representation urban stormwater removal all the more difficult and costly. If theirs high amount of rainfall the impacts runoff volume on the sidewalks, land use and land cover, roadways, and other impervious surfaces of an urban center, such as the district of town of east Africa on streams and rivers. Hydrologic response of an urban area is changed. As drainage areas become increasingly impervious, stormwater runoff volumes, flows, and velocities increase, while base groundwater flows decrease.

B: Characteristics of the catchment area

Prior to developing any form of response to stormwater issues, it is vital that a study is carried out to identify the exact characteristics of the catchment or mini-catchment area (size, land use plan).

C: Soil type

The type of soil will directly affect the infiltration capacity. Lateritic soils, in particular, are highly impermeable. When rainfalls on to undeveloped land, most of the water will soak into the topsoil and slowly percolate through the soil to the nearest watercourses or groundwater. A small proportion of the rainfall usually 15 to 20 % becomes direct surface runoff that usually drains into watercourses slowly because the ground surface is rough. Permeability and infiltration are the principal data required to classify soils into Hydrologic Soils Groups (HSG). According to ERA drainage manual of 2013 the hydrological soil group in Ethiopia in four categories based on infiltration rates, the Soil Conservation Service (SCS) has divided soils into four hydrologic soil groups as follows (ERA, 2013) .

Group A: Sand, loamy sand or sandy loam. These are Soils which have a low runoff potential due to high infiltration rates. These soils primarily consist of deep, well-drained sands and gravels.

Group B: Silt loam, or loam. These Soils are having a moderately low runoff potential due to moderate infiltration rates. These soils primarily consist of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

Group C: Sandy clay loam. These Soils are having a moderately high runoff potential due to slow infiltration rates.

Group D: Clay loam, silty clay loam, sandy clay, silty clay or clay. These Soils are having a high runoff potential due to very slow infiltration rates. These soils primarily consist of clays with high swelling potential, soils with permanently-high water tables, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious parent material. As the slope of the drainage basin increases, the selected runoff coefficient C should also increase. This is caused by the fact that as the slope of the catchment area increases, runoff volume is high because the surface area of soil type is maximum, the velocity of overland and channel flow will increase allowing less opportunity for water to infiltrate the ground surface.

D: Extension and densification of urban areas

Although, overall, urban growth rates have fallen over the last 20 years, in most developing countries they remain very high, both in capital and secondary cities. Thus, the urban landscape is constantly expanding and becoming denser, extending into areas with no stormwater drainage system.

E: Impermeability

Increasing urbanization (housing developments, road construction) leads to increased soil stopping; thus, water is no longer absorbed by the soil but runs off along the surface, increasing the quantities of water to be treated and preventing groundwater recharge. It is estimated that a city with relatively low housing density is able to absorb up to 35% of its surface runoff, whereas a city with high housing density can absorb only 10%.

With urbanization, impermeability increases with the increase in impervious surfaces (residential houses, commercial buildings, paved roads, parking lots), drainage pattern changes, overland flow gets faster, flooding and environmental problems such as land degradation increases. It is a crucial problem facing the existing and future environmental conditions of urban centers (FUPCoB, 2008).

F: Degradation of plant cover

The degradation of plant cover both upstream and within cities increases the surface runoff within the entire urban catchment. Within the city itself, during heavy rains, this degradation of plant cover increases both them speed and volume of runoff in urban areas, causing soil erosion, landslides and clogging the networks with solid particles (sediment and urban waste). In Ethiopian context, where watersheds of many urban centers receive significant amount of annual rainfall and where rainfall intensity is generally high, control of runoff at the source, flood protection, and safe disposal of the excess water/runoff through proper drainage facilities become essential (NUPI, 2000).

G: Slope

In the nearly level slope of area (0-1) degree the surface runoff is low and also the percolate rain water into the ground is increase then, its area were considered low runoff impact with in the town, whereas high slope area (>14) degree, facilitate high runoff and less infiltration, caused flooding with in the urbanization (WAIKAR, 2014).

2.2.2. Conventional and Sustainable stormwater management

CSM techniques are designed to collect and transport street stormwater runoff as quick as possible through drainage channels and pipes (conventional drainage) from urban areas (Zhou, 2014). This type of method will only transport stormwater from one section of the basin to another in order to avoid street flooding in urban areas.

In the United States of America, the term Low-Impact Development (LID) or sometimes referred to as green infrastructure (GI) which, is used to describe sustainable urban drainage systems (SUDS). The land development the negative impacts of urban stormwater runoff will be reduce if the natural systems are implemented during street development (Pazwash, 2011).This can be accomplished by using the natural drainage system to infiltrate and divert storm-runoff into the natural landscape via landscape planters, rain gardens and swales.

Table 2. 1 Conventional Stormwater Management strategies (Dhalla and Zimmer, 2010).

Factor	CSWM	SSWM
Drainage	-High run off convinces capacity and efficiency. which Reduced potential for flooding. But decreases ground water and change the natural hydrology of site.	-Returns storm water runoff on site and promote infiltration (therefore reduced flooding) and ground water recharge through and natural drainage feature
Environmental	-Conventional system could have an over flow effect specially on high precipitation event and can cause flood erosion.	-Less disturbances and conservation of natural feature by enhancing the aesthetic value
Cost	-High construction cost for stormwater management	-More economical than conventional

2.2.3. Best management practices

BMPs require on-going inspection and maintenance into perpetuity to preserve intended pollution control and flow control performance as well as to solve the problem of urban storm water drainage that has been hindering the drainage systems. This sustainable stormwater strategy uses natural system to improve the well-being of watershed, improve comfort and address biodiversity as well as reduce and reduce risk of flooding in urban areas by using natural green techniques like bio retention, swale and minimizing impermeable surfaces for regulate stormwateter (Kloss and lucks, 2008).

Table 2.2. Techniques to manage surface runoff for BMP (Parkinson,2010).

Storage Type Devices	Infiltration Type Devices
1. Detention Ponds	1. Infiltration Trenches
2. Retention Ponds	2. Grass Filter Stripes
3. Onsite Detention	3. Grassed Swales
4. Rainwater Harvesting	4. Pervious Pavements
5. Green Roofs (living roofs and Constructed Wetlands	5. Infiltration Basin

2.3. Storm Water Drainage System

A storm drain is that portion of the roadway drainage system that receives runoff from inlets and conveys the runoff to some point where it can be discharged into a ditch, channel, stream, manhole ,pond, lake and drainage through storm water drainage pipes (FUPCoB, 2008) .

Storm drains shall be designed using the following criteria where applicable:

A. Pipe sizes should not decrease in the downstream direction even though an increase in slope would allow a smaller size.
B. Pipe slopes should conform to the original ground slope as far as possible to minimize excavation.
C. Maximum grade on which concrete pipe should be placed is 10%.
D. Minimum self-cleaning velocity of 0.76 m/s should be maintained wherever possible
E. Minimum pipe size is 375 mm
F. Existing drainage facilities that are not to be incorporated into the proposed drainage system are to be completely removed if they are in conflict with any element of the proposed construction.
G. The drainage layout should attempt to avoid conflicts with existing underground utilities and such items as utility poles, water supply lines and telephone cables.
H. Precast manholes or inlets shall not be used for pipes 1350 mm or larger diameter or when three or more pipes tie in and at least two of them are connected at some angles. When these conditions exist, cast-in-place inlets or manholes are more practical.

Drainage serves for removal of excess water from an area by surface or subsurface means. Excess water in urban areas may be domestic and industrial wastewater or storm runoff. The need for urban drainage systems seems to be obvious considering the number of people living in urban areas and the effects of wastewaters on health or the threat of stormwater flooding. Appropriate disposal of wastewater and storm runoff contributes to human well-being and to the proper functioning of urban communities (Viessman etal, 2009). Urban drainage systems are needed in proposed developed urban areas because of the interaction between human activity and the natural water circulation. The system can be represented as a network consisting of catchments and sub catchments, Manhole, Conduit and outlet. The components of the system are defined below (Linmie, 2004).

Catchment: -A catchment is the area collecting water from nearby higher terrain surface, which is delineated by topographic contour lines.

Manhole: - Manholes **a**re junctions to link the sewers. They also provide storm water transition between surface and subsurface systems. Manholes should be provided at intersections of storm water drains, junctions between different size of storm water drains, where a storm water drain changes direction/gradient and on long straight lengths.

Manholes shall normally be designed at each change of direction or gradient, and at each branching line and at a spacing of not more than 100 m and on stormwater pipelines equal to or greater than 900mm diameter, the spacing of manholes may be extended up to 200m, Manholes may either be cast in situ or and uniform curvature on the pipeline may be permitted providing that joint deflections of precast concrete in accordance with the Standard Technical Specifications (City Waters Unit Manager, 2010).

Conduit: - Transport flow in the system, and are often open channels or closed sewers with regular or irregular cross sections.

Outlet: - The most downstream component of the urban drainage system, which discharges

The separated system comprises two separate pipelines for waste and storm water protecting from flooding in the basement and floors of houses in low-lying during. Extreme rainfall, as well as avoiding the release of pollutants into the environment (EPA, 1999). The Streets are designed not only to carry traffic, but stormwater runoff as well. The main purpose is for traffic movement therefore, the drainage purpose is passive and must not interfere with the traffic function of the street (USWD, 2010).

2.3.1. General concept of urban Flooding

A flood can be described as an event with extreme runoff water (EEA, 2001). General and fairly common classification is based on the geographical area (rural or urban flooding) in combination with the water body which is responsible of the flood (coastal, river, flash precipitation, groundwater or sewer flooding) (Ashely et el, 2007) .

flood risk assessment is the identification, quantification and communication of flood risk using the source-pathway-receptor model. It examines the sources of flooding and the pathways by which floodwaters might reach receptors, such as people, property and the environment to determine the likelihood of them being affected by flooding (OPW, 2009).

In the assessments of flood risk, the source-pathway-receptor model means that: -

Source: -where the source of water to create the flood comes from rainfall

Pathway: -the way and the integrations of drainage systems where the flooded water passes through.

Receptor: -the final destination where the flooded water affects (Infrastructures and peoples).

Flood risk captures the impact flooding has on society. The concept of flood risk, which is function of the probability that a flood event will occur and the consequences damage for human health and infrastructures associated with a flood event (Senarathne , 2005).Simulation models for urban flood risk analysis are required to accurately describe the hydraulic phenomena of surcharged and flooded drainage systems (Schmitt, 1999).Some of them listed below :-

A. Identify the current capacity of the various drainage systems.
B. The transition from free surface flow to pressure flow in the sewer pipes.
C. The rise of water level above ground level with water escaping from the drainage systems.
D. The occurrence of surface flow during surface flooding.

2.3.1.1. Deficiencies in the system and causes of flooding

Surface water flooding typically arises as a result of intense rainfall, often of short duration that is unable to soak into the ground or enter drainage systems. There is inherent link between sewer flooding and overland flow/surface water flooding. This source of flooding can be compounded when combined with impermeable sub-soils, significant areas of development with associated hard standing areas or areas of open grassland. As the majority of the study area is heavily developed, the risk of surface water flooding is increased (Lambeth, 2013).

The major deficiencies in the storm water drainage system which causes flooding are given below: -

A. Many gradients are flat and the drains are affected by flows
B. Interconnection of storm water and sewerage networks
C. Access for maintenance to some drains is restricted by development over the manholes.
D. A large number of drains were found to be of inadequate capacity barriers were there in the larger drain.

2.3.1.2. Excess Sediment and Garbage.

Urban areas in developing countries have significant proportions of exposed soil liable to erosion and giving rise to large quantities of sediment. Building sites, whether in areas where the city is expanding or within the developed urban area, do not normally have controls for erosion prevention or for retaining sediment so that it does not reach the streets, storm drains and urban rivers. It is no exaggeration to say that 10 to 15% of urbanized area in developing countries contributes extensively to sediment production and transport. The amount of garbage entering the drainage network is reduced corresponding to a production of 0.4 to 0.8% of total garbage produced. For developing countries, the rate of garbage accumulation in the streets is certainly higher, since in some parts of the cities the storm-drain network is used for garbage disposal (Tucci, 2000).

2.3.1.3. Impacts of Urban Runoff

The collective impacts of the rooftops, sidewalks, roadways, and other impervious surfaces of an urban center, such as the district of Columbia, on streams and rivers have historically been divided into two categories. First, the hydrologic response of an urban area is changed. As drainage areas become increasingly impervious, stormwater runoff volumes, flows, and velocities increase, while base groundwater flows decrease. Small annual storm events that would be captured by the plants and soils of an undeveloped landscape are delivered quickly and efficiently to the receiving pipe network and streams in a city. Second, human activities in the city generate increased pollutant loads, ranging from heavy automobile traffic to use of various chemicals (Ellicott, 2012).

Land use and land cover

The type of Land use and in a given watershed has also great effect on the runoff yield. E.g. Local Street that integrates green cover (trees or grasses) with permeable surface contributes less runoff because water is absorbed more into soil (CLUVA, 2013).

For the impacts of urban runoff each land use and land cover data on the town, annual storm water run-off volume was calculated, using formula having composite run-off coefficient. A formula given by the rational method was used for calculating potential run-off from a watershed. Three terms catchment area, composite run-off coefficient and annual rainfall depth were multiplied as shown below. This formula gives an approximate annual run-off volume.

The total run-off volume was obtained by summing up individual run-off volume from each land use and land cover. Three terms - catchment area, composite run-off coefficient and annual rainfall depth were multiplied as shown below. The drainage area is probably the single most important watershed characteristic for hydrologic design. It reflects the volume of water that can be generated from rainfall. It is common in hydrologic design to assume a constant depth of rainfall occurring uniformly over the watershed. Under this assumption, the volume of water available for runoff would be the product of the average rainfall depth, the drainage and runoff coefficient area. This formula gives an approximate annual run-off volume for rational method (Asherand and Bajracharya, 2015).

$$V=A_{lulc}\times C\times R_D \quad \text{...2.1}$$

V= Runoff of volume in urban area

A_{lulc} =Area of Land use and Land cover of town

C = Composite Run-off Coefficient of the Land use and Land cover of town

RD = Annual rainfall in mm [average rainfall in mm for town]

In the study area of land use land cover data from satellite data for this data to be checked the parameter by using Kappa coefficient estimation used for agreement between model predication and reality (Congaluation, 1991).

2.3.1.4. Hydrologic analysis of stormwater drainage structure

In the hydrologic analysis for a drainage structure, it must be recognized that there are many variable factors that affect floods. Some of the factors which need to be recognized and considered on an individual site-by-site basis are things such as: Rainfall amount and storm distribution Drainage area size, Ground cover, land use land cover, material of drainage structure, Type of soil, Slopes of terrain and Storage potential (overbank, ponds, wetlands, reservoirs, channels) (Aydagne , 2007).

2.3.1.5. Effects of urban expansion

Urbanization alters natural conditions by increasing impervious area and by creating new pathways of stormwater flow. This results in an increase in direct runoff and decreases in infiltration and evapotranspiration The decrease in infiltration that occurs with urbanization also reduces soil moisture replenishment and groundwater recharge. The imperviousness of urban areas along with the greater hydraulic efficiency of urban drainage infrastructure causes more rapid stream responses and greater peak flows. Infiltration and evapotranspiration during the summer are less for developed areas than for undeveloped areas (Adersone, 2011).

2.4. Arc hydro

Arc Hydro is a model developed for building hydrologic information systems to synthesize geospatial and temporal water resources data that support hydrologic modelling and analysis. The model is developed as an Add-on to Arc GIs software. Most watershed managers use this facility more than other advanced hydrologic analysis for their watershed management requirement. At the outlet, a raster analysis is performed to generate data on flow direction, flow accumulation, stream definition, stream segmentation, and finally watershed delineation .stream networks created from DEMs using the Spatial Analyst, are the primary inputs to most surface hydrologic models for the fields such as urban and regional planning, agriculture and forest (Francisco Olivera and David Maidment, 1999).

CHAPTER THREE

MATERIAL AND METHODS

3.1. Description of the study area

Bure is one of the towns in West Gojam Administrative Zones in Amhara National Regional State. The town is approximately located between$10^{0}17'$- 10 $^{0}45'$N latitude and $37^{0}00'$-$37^{0}10'$E longitude (Shitahun, 2009) and elevation of 2107 meters above sea level and the city covers a total area of 12.4 square kilometers (**1240** ha) (Bure municipality, 2014).The boundary main town of the Bure is 400 km northwest of Addis Ababa and 148 km southwest of Bahir Dar. And also the capital majority of social and economic infrastructure rapidly growth in the country. It has been expansion industry, communications center**,** health center**,** religious facilities**,** education and people coming from all corners of the country side in search of better employment opportunities and services and also the connection point between Wolega, Gondar and Shew for business activity and agricultural training collage, University, collage, mineral water factory and ongoing mega industry park project.

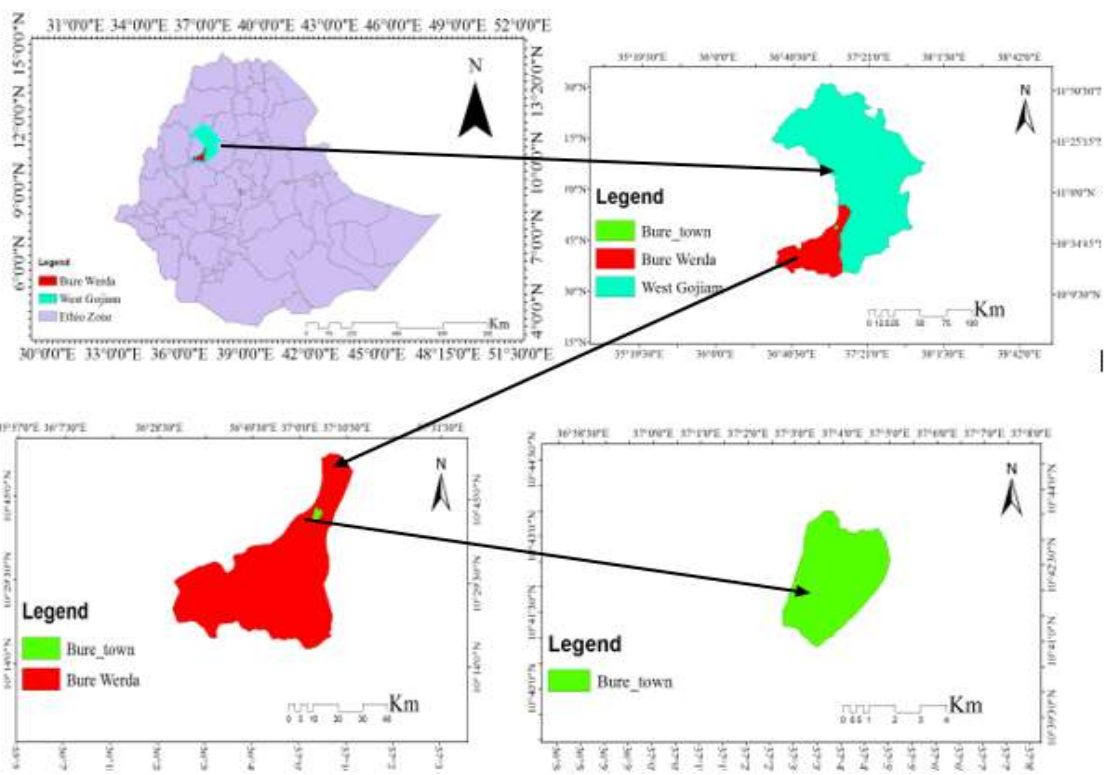

Figure 3.1: Location Map of the Study area

3.1.1. Climate

Based on Rainfall, the climate of the area can be categorized in to two broad seasons: the dry season (winter) which covers the period from October to May and the Wet season extends from June to September, with slight rainfall during fall and spring .The maximum and minimum monthly temperature in the watershed varies between 23°C-29.9°C and 70C-140C respectively(Aster and Selesh, 2009).

3.1.2. Area coverage

According to the master plan by Bure City in 2010 GC, which covers 1240 hectares or 12.40km2 the area of the city that classified into Housing areas, Gorge and road areas, river line, storage area, grounds, infrastructure, market, religious, cemetery, recreation areas, mixed use, social services, Vegetation, forests and other types of development purposes.

3.2 Data Collection

3.2.1. Data Types and Sources

This part contains of the types and sources of data which were used in this study. Consequently, the qualitative as well as quantitative type of data has been used for this research. Data sources for this research were both primary and secondary sources.

3.2.1.1. Primary data sources

Field survey was employed to measure the existing drainage lines located in the study area, to gather information about the current condition of the drainage system with the help of field survey/observation and interview were the primary data sources which were engaged in this study. In this research Interview with concerning body like head of municipality officer, industry manger, household, government civil servant and water bureau concerning the effect of water drainage stormwater management challenges as well as environmental challenges relating to the improper utilization of the drainage systems in the chosen locations. Using information gathering for Small Populations of the entire population as the sample for cost considerations, eliminates sampling error and provides data on all the individuals in the entire population make this impossible for large populations. Generally, this was employed for the resident in the study area to collect data related to the major challenges to storm water drainage management, impacts of drainage system of Bure storm water drainage system and damages caused by solid waste disposal from community point of view so as to handle the challenges of the drainage system in the study area. The community in the study area were interviewed to get reliable data as they are the most vulnerable people in the past years and they have been observing the flooding problem, the challenge that has been faced over the year's survey/observation and interview were the primary data sources which were engaged in this study.

3.2.1.2 Secondary data sources

Meteorological data (rainfall data) from National Meteorological Service Agency of Ethiopia, contour map, Digital Elevation Model (DEM), Land Use and Land Cover Data, geological, Soil Data, other findings/literatures and reports were Secondary data sources which were used for this particular research.

This was important to get the harvesting information on the over-looked causes of poor drainage challenges and unconstructed storm water drainage. Other secondary sources of information that was used include books, journals and manuals.

Table 3:1. Types of data collected and their sources

Types Data	Sources of Data
Meteorological Data	National Meteorological Service Agency Addis Ababa Ethiopia, Hydrology department
Topographic Maps	Ethiopian Mapping Authority Addis Ababa, Ethiopia?
Soil	Ministry of water ,Irrigation and electricity Addis Ababa Ethiopia.
land cover and Land Use Maps	From USGS 30*30 for satellite data of land sate for different time of period interval.
Digital elevation Model (30mx30m resolution)	Ministry of water ,Irrigation and electricity Addis Ababa Ethiopia
Base map	Bure Town municipality
Assessment of Existing Drainage System of the town	Collected from field by using camera

3.2.1.3. Different Types Materials used in Research

There are different types of software used in this study. These are in given below. All this software is used in this study site.

Table 3:2 Software's and their uses in the study Area.

Software	Their uses
Arch hydro 10.4.1	Stream Network delineation of a town by input data for DEM
Arch GIS 10.4.1	Land use and land cover map delineation and fixing number drainage outlet of town
AutoCAD 2007	To estimate area of urban sub- catchment with in the topography guided and also fixing number of manhole and conduit sideways of road alignment.
Bentley Civil Storm V8i	To be flood assessment of stormwate drainage system
Spreadsheet 2016	To plot graph and chart and calculation

3.2.2. Meteorological Data Collection and Analysis

3.2.2.1. Meteorological Data Collection

In Ethiopia, the source of raw metrological data is the National metrological service agency (NMA). A request of metrological data such as rainfall and temperature of study area was made to the agency. Following the approval of the agency 's higher official daily data of existing years' period is collected. From the entire available automatic recording stations those which are in or proximate to the watersheds considered for the research work were selected. As a result, a total of four station rainfall stations were selected for use in the research work. The four stations are collected for this study; those are Bure, Sebader, Tilili and Finote Selam. The daily metrological data exist at this station from 1985 to 2016 with missed certain monthly and daily data.

3.2.2.2. Rainfall Data Screening

Rough rainfall data screening in the study area was first done by visual inspection of daily rainfall data. Because of long braking in rainfall records of some stations and absence of lengthy overlapping period of record this inspection was done in the record of the hydrologic years of 1985 to 2016. Normal ratio method used to fill missing data.

3.2.2.3. Filling in Missing Rainfall Data

A number of methods have been proposed for estimate missing rainfall data. The station average method is the simplest method. The station average method for filling missing data is conceptually the same as the station average method for estimating a mean precipitation. The normal-ratio method is conceptually simple; it differs from the station-average method of that the average annual rainfall is used in deriving weights. If the total annual rainfall at any of the N region gauges differs from the annual rainfall at the point of interest by more than 10%, the normal-ratio method is preferable. This thesis uses normal-ratio method for filling the missing rainfall data. For total annual rainfall at station for more than10% normal-ratio method used. Among different method Normal ratio method is one them which is recommended to estimate missing rainfall data in regions where annual rainfall between stations differ by more than 10% (Garg, 2005).

If for example rainfall data at day 1 is missed from station Z having mean annual rainfall of Nz and there are three surrounding stations with mean annual rainfall of N1, N2, and N3 then the missing data Pz can be estimated (Yilma, 2005).

$$Pz=\frac{1}{3}\left(P1\frac{NZ}{N1}+P2\frac{NZ}{N2}+P3\frac{NZ}{N3}\right) \qquad 3.1$$

Where: Pz - missing rainfall data (daily, monthly or yearly)

P1, P2 and P3 – rainfall data at nearest different station (daily, monthly or yearly)

Nz - mean annual rainfall at missed station

N1, N2, and N3- mean annual rainfall at different nearest station

3.2.2.4. Data Consistency Test

The daily heaviest rainfall data of Bure meteorological station from 1985 to 2016 is taken for the design. Hence, 32 years of daily heaviest rainfall data is available. These data should be checked for its consistency by higher and lower outlier testes.

A: -Test for Higher outlier

$$\text{Higher outlier } YH=\bar{Y}+K_n\delta n-1 \qquad 3.2$$

Where: $\bar{Y}$ = mean of data in log unity

K_n= from table for sample size N (Vente Chow, 1998)

$\partial n-1=$ standard devotion

$$\text{Higher outlier test}=10^{YH} \qquad 3.3$$

B: - Test for Lower outlier

$YL = \bar{Y} - K_n \delta n - 1$……………………………………………………………………......3.4

Lower outlier=10^{YL}=………………………………………………………… ………….3.5

3.2.2.5. Checking Data Reliability

Relative standard Relative standard less than 10% the data series could be regarded as reliable adequate (Subramanya, 2008)

N Number of data

$\delta n - 1$ Standard deviation

$\bar{X}$ Mean

Standard error of mean, $\delta n = \frac{\delta n-1}{\sqrt{n}}$………………………………………………………….3.6

Relative standard=$\frac{\delta n}{x-} * 100$………………………………………………...... ………...3.7

3.3. Design rain fall analysis

3.3.1. Estimation of average depth of rainfall over a catchment

Rainfall depth

The most hydrological problems require knowledge of the average depth of rainfall over a significant area such as a basin. The rain catch at one station in a basin may be different from that of other stations in the same basin (Asquith, 1999).

A: Point Rainfall

Point rainfall is precipitation occurring at a single point in space as opposed to areal precipitation which is precipitation over a region. For point precipitation frequency analysis, the annual maximum precipitation for a given duration is selected by applying statistical analysis to historical records. For each duration frequency analysis is performed on the data to derive the design precipitation depths for various return periods (Vente Chow, 1998).

B: Area rainfall

Frequency analysis of precipitation over an area has not been as well developed as analysis of point precipitation. explain that, in the absence of information on the true probability distribution of areal precipitation, point precipitation estimates are usually expected to develop an average precipitation depth over an area (Vente Chow, 1998).

Due to the lack of information on the probability distribution of areal precipitation, point rainfall is used collectively to estimate areal average rainfall. In hydrologic design point of view, storm spatial characteristics become more important as the size of the watershed of interest increases. The main reason to consider areal adjustment for a large area is that the likelihood associated with a high rainfall depth over a large area is not the same as that depth at a single point.

Area rainfall requires a method of estimating aerial average rainfall over a basin by using: - Arithmetic average method to be used for this research by judgment consideration of quality and nature of the data, and the importance, use, and required precision of the result rainfall data used. Mean annual rainfall for a given basin/catchment/area is computed as the arithmetic average of total yearly rainfall for several consecutive years. Mean annual rainfall obtained from rainfall records of about 30–40 years is expected to be true long-term mean annual rainfall with an error of about less than 2% and is acceptable for all types of engineering problems (Aswa, 2005).Therefore, arithmetic mean method is appropriate for the study area and were used for estimation annual runoff volume in 31 year is the sum of average depth of rainfall over a Bure catchment it is found in appendixes.

3.3.2. Return period

It is the average time interval between the occurrence of storms and floods of a given magnitude. The historical rainfall data available is a 24hr duration rainfall flood frequency analysis is utilized to determine the magnitude of flood with a particular probability of exceedances from a statistical of record flood. Any probability distribution can be used as the model but the reliability of the distribution is checked by the goodness of fit tests. Among many method, Log Pearson Type III methods are used for these research.

Recommendations for a better planning Preparation of a long-range strategy plan for the entire urban region with a 25 year possibility (Ellicott, 2012).The areas of concern would cover:-

A. Storm water drainage system and disposal
B. Sewage treatment and disposal
C. Broad delineations of land use
D. Strategies for risk mitigation and Solid waste secondary collection and disposal.

3.3.3. Design Rain fall Computation of shorter duration

After checking the consistency of the data for both higher and lower outlier, the 32 years' data for the analysis (Now the data is reduced to 31 years). These rainfall analysis and processing is aimed at determination of appropriate Intensity-Duration Frequency relationship. Extreme rainfall depth at Bure town station for different return periods was determined using (Subramanya, 2008).

A: Log Pearson Type III distributions analysis.

$Y_T = Y_{avg} + K_T*Sy$……………………………………………………………………...3.8

Where: Y_T = Log X_T –logarithm of Rainfall depth (X_T) at return period T years [mm]

Y_{avg}= Mean value of logarithmic rainfall data (daily) [mm]

Sy = Standard deviation [mm]

$$Yavg = \frac{\sum y}{n}$$

$$sy = \sqrt{\frac{\sum y^2 - \frac{1}{n}(\sum y)^2}{n-1}}$$

y =logarithm of rain falls depth(x)

n= total number of x (individual)

KT = Log Pearson Type III distribution frequency factor (taken from appendix table)

B: Gumbel method analysis

$X_T = \bar{X} + KS_Y$…………………………………………………………………….................3.9

$$sy = \sqrt{\frac{\sum y^2 - \frac{1}{n}(\sum 1y^2}{n-1}}$$

Sy: Stander deviations of sample size N

K= frequency factors expressed as

$$K = \frac{Yt - \bar{yn}}{sn}$$

Yn and sn reduced standard deviations, as sample N in the table (Vente Chow, 1998).

3.4. Stream Network Delineation Using ArcGIS Arc Hydro Tools

The hydrologic tools allow identifying sinks, determining flow direction, calculating flow accumulation, Stream Definition, Stream Segmentation, Catchment Polygon Processing, Drainage line, point, and locating outlet point catchment area selection. All spatial analyst tools that are used for delineating stream network available in Arc Toolbox. The area upon which waterfalls, and the network through which it travels to an outlet, is referred to as a drainage system**.** Using a digital elevation model (DEM) as input, it is possible to delineate a drainage system using the following steps as follows (Parmenter and Melcher, 2012).

1. Fill: This step will fill the sinks of clipped DEM
2. Flow Direction: Based my study area (Clipped DEM) – this will compute for every cell the direction that water would flow through it
3. Flow Accumulation: based on the new filled Flow Direction grid areas of higher values are where water collects and drains. The Flow Accumulation grid will allow the software to determine the area draining to any specified point on the DEM
4. Stream definition: computes a stream grid based on a flow accumulation grid and a user defined threshold. The cells in the input flow accumulation grid that have a value greater than the threshold are assigned a value of 1 in the stream grid.
5. The stream segmentation: function takes the flow direction grid and the output of stream definition grid which is extracted in the earlier steps as an input and stream link grid will be the output
6. Catchment grid: The value corresponds to the value carried by the stream segment that drains that area, defined in the stream segment link grid.
7. Drainage Line: feature classes which are extracted from the input stream grid and flow direction grids. The activity performed by this function is the identification of upstream-downstream relationship.
8. Drainage point Processing: - function on terrain processing menu allows generation of drainage points associated to the drainage line.

Generally, the locating of outlet Point in the town in order to use the base map Auto cad 2007 of sub-catchment which can easily be imported to the Arc GIS window. By superimposing the drawing file over the natural drainage line and point more accumulating stream flow for the watershed and the lowest ground control point fixing the outlet point can easily be extracted.

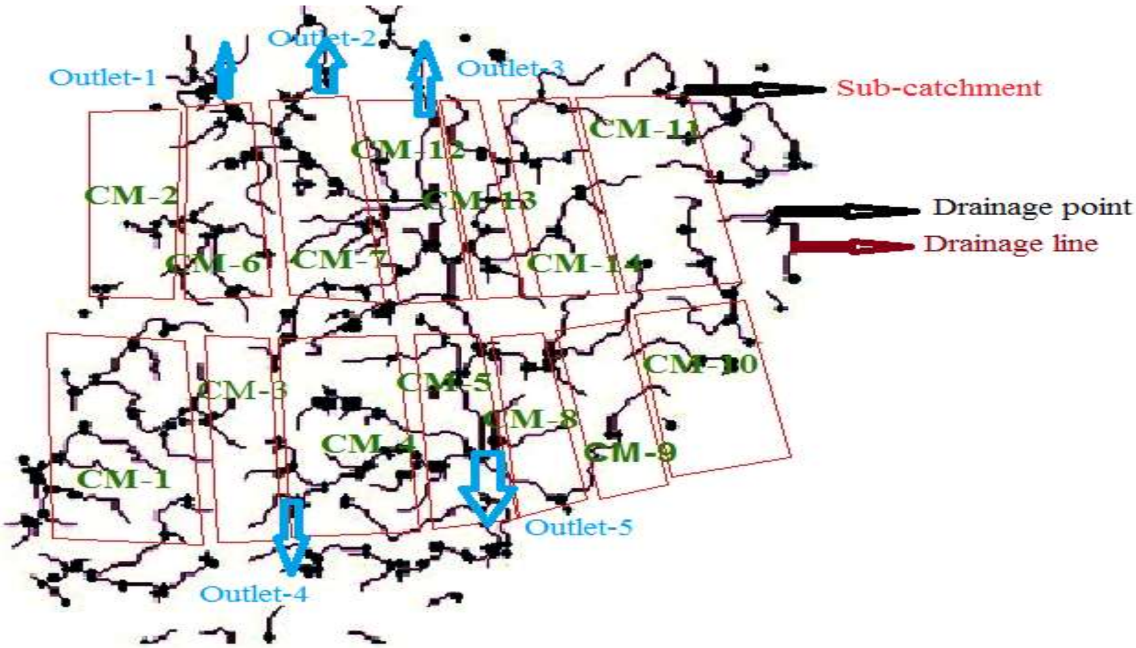

Figure 3. 2. Locating Outlet Point on Bure Town

3.5. Intensity-Duration-Frequency (IDF) Curves

The rainfall depths obtained from gauging station are of 24hr duration depth and Bure town is found Region A2 between Bahir Dar and Debre Markos. Design and analysis of drainage structures require rainfall intensity duration relationship of shorter duration. Because rainfall data of shorter duration is unavailable, appropriate IDF derivation for shorter duration is required for (ERA, 2013). suggests the following equation.

$$Rt/R24=\frac{t}{24}\left[\left(\frac{(b+24)^{n}}{(b+t)^{n}}\right)\right. \quad \text{.......} \quad 3.10$$

Where Rt/Rt=rainfall ratio=Rt: R24

Rt= rainfall in given duration"t"in hour

R24=rainfall in 24-hour t=time in hour n=0.9, b=0.3(based on studies of large number of gauges in east Africa (Waikar and Undergonkar, 2015).

3.6. Hydrological Estimation for Determining Peak runoff

3.6.1. Rational Method

The main purpose of hydrologic analysis is to determine the maximum amount of run-off (peak discharge) that can be accumulated at certain storm drainage outlet (usually a ditch) along a highway/access road alignment section for the design of stormwater drainage system, The Rational Method considers the entire drainage area as a single unit and estimates the peak discharge at the most downstream point of that area. It is, one of the most commonly used simplified models for road storm drainage, is primarily based on the concept that the peak discharge from a watershed will always occur when the rain lasts long enough at its maximum intensity to enable all portions of the basin to contribute to the flow. For this thesis is appropriate because of area for each catchment is less than 50 hectares (0.5sqkm).

The peak runoff is given by the following expression:

$$Q = 0.00278 * C * I * A \quad \text{……………………………………………………}3.11$$

Where Q – Discharge at outlet (m3/s)

C – Rainfall-Runoff Coefficient

I – Maximum probable rainfall Intensity (mm/hr)

A– Catchment Area (hectares).

The stormwater drainage outlet usually has a delineated tributary catchment area/ watershed, designated with variable A(area) in the above equation, that contributes runoff to it, the size of which can be easily determined using Auto-cad, by the guiding of maps topographic survey.

The main input variable to use rational method is; rainfall intensity, rainfall duration, rainfall frequency, catchment area, hydrologic abstractions, runoff concentration, run-off diffusion but, the peak discharge is the product of, runoff coefficient, rainfall intensity and catchment area. although simplistic, the rational method, especially coupled with rainfall frequency analysis and a judicious fine-tuning of runoff coefficients, is generally considered to serve justice to the determination of runoff quantity for storm drainage purposes with reasonable dependability**.**

Limitation of Rational Method (ERA, 2013).

1. The rainfall intensity is uniform over a time duration equal to the time of concentration.
2. The area limitation of 50 hectares,
3. The peak discharge occurs when all of the watershed is contributing,
4. The frequency of the computed peak flow is equal to the frequency of the rainfall intensity.
5. The runoff coefficient (C) is constant during the storm event

3.6.1.1. Runoff Coefficient Determination

The runoff coefficient (C) is the variable of the Rational Method least susceptible to precise determination and requires judgment. This variable represents the ratio of runoff to rainfall it represents the interaction of many factors, including the storage of water in surface depressions, infiltration, antecedent moisture, ground cover, ground slopes and soil types. Runoff coefficients are theoretically restricted to the range of 0 to 1.0. Runoff coefficient values for pervious surfaces by selected hydrologic soil groups and slope range given in the (ERA, 2013) reproduced as Table below appendices is used here in this project accordingly. Equation below is used to determine weighted average runoff coefficient values for each catchment area under rational method using land use map of landsate satellite 1986,2010 and 2017, but the study area runoff coefficient to be used is 2017 land use land cover in Bure town. Land use composition of the in Bure town the total area is 1240 ha. The runoff coefficient taking the average land use land cover in current condition 2017 because of for time to time the runoff in urban are is increasing, to improper land use planning for the town, and there is no organized data regarding land use in Bure town then 1986 and 2010 and also to used overall the catchment. which is essential to investigate the runoff coefficient in detail in the following.

$$C_{wigted=}\frac{\sum Ai*Ci}{AT} \quad \text{……………………………………………..........................3.12}$$

Where Ci- Runoff coefficient for a given hydrologic soil group area

Ai -Area under each hydrologic soil group

AT -Total catchment area considered of town

In the study area run off coeffieant was taken from land use land cover in 2017 so using satellite data taken to cheek the data accurate or note estimated in the appendix is given.

Ground truth represent a powerful and attractive that can be used for investigation and preliminary studies with suitable accuracy and low cost. Since the image from ground truth with high spatial resolution are free for public and can be used directly in land use land cover mapping in small geographical extend. A study which conduct by (Abineh and Zubariual , 2015). The result of accuracy assessment of land use and land cover with the help of ground truth was more than 75% which is acceptable.

$$\text{Kappa coefficient (Ka)}= \frac{NZi-\sum Xi*\sum Yi}{N^2-\sum Xi*\sum Yi} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.13$$

N= Total number of observation

Zi=sum of corrects in the digonale matrixcs.

$\sum Xi$= Sum of all the row total

$\sum Yi$= Sum of all the coloumne total

3.6.1.2. Rainfall Intensity

The rainfall intensity (I) is the average rainfall rate in mm/hr. for duration equal to the time of concentration for a selected return period. Once a particular return period has been selected for design and a time of concentration calculated for the catchment area, the rainfall intensity can be determined from Rainfall-Intensity-Duration curves. Calculation of Tc is discussed in detail in the next section.

3.6.1.3. Catchment Area

Like rational method, the catchment area can be determined from Base maps and site observation. However, for large catchment areas Bure town is necessary to divide the area into sub-catchment areas using Auto CAD 2007 to account for common outlet of the town in natural drainage system.

3.6.1.4. Time of Concentration

Use of the Rational Method requires calculating the time of concentration (Tc) for each design point within the drainage basin. The duration of rainfall is then set equal to the time of concentration and is used to estimate the design average rainfall intensity (I). The basin time of concentration is defined as the time required for water to flow from the most remote part of the drainage area to the point of interest for discharge calculations.

The time of concentration to any point in a storm drainage system is the sum of the inlet time to (the time it takes for flow from the remotest point to reach the sewer inlet), and the flow time tf in the upstream sewers connected to the outer point:

The velocity of flow depends on the catchment characteristics and slope of the water course by using manning equation. Many empirical equations are available for calculating time of concentration for a watershed. Among many that three equations are used for this thesis (AACRA, 2003).

1. Sheet flow
2. Shallow concentrated flow, and
3. Open channel flow

1.Sheet Flow Time

Sheet flow is flow over plan surfaces. It usually occurs in the headwater of the streams (usually for the first 100-130m run). With sheet flow, the friction value (Manning's roughness coefficient) which take into account the effect of raindrop impact, drag over the plan and other ground cover barriers has a significant impact on the overall sheet flow travel time determination. Manning's kinematic solution is used to compute sheet flow travel time in given below for CM-1, but other is estimated in appendixes (Overton and Meadows, 2008).

$Tt=[0.091(nL)^{0.8}/(P2)^{0.5}S^{0.4}]$ ……………………………………………………….3.14

Where: Tt = travel time, hr

n = Manning's roughness coefficient

L = flow length, m

P2 = 2-year, 24-hour rainfall, mm

S = slope of hydraulic grade line (land slope), m/m based on topographic map

2.Shallow concentrated flow

After a maximum of 100 meters, sheet flow usually becomes shallow concentrated flow. And the average velocity for this flow can be determined by the following formula, in which average velocity is a function of watercourse slope and type of channel (ERA, 2002).

For Unpaved $V= 4.9178S^{0.8}$……………………………………………………………….3.15

Paved $V =6.196S^{0.5}$…………………………………………………… ………………………….3.16

Where V = average velocity, m/s

S = slope of hydraulic grade line (watercourse slope), m/m overland flow time

$$Tt=\frac{L}{360V}$$ ……3.17

Where: Tt = travel time, hr, L = flow length, m, V = average velocity, m/s and 3600 = conversion factor from seconds to hours.

3.Open Channels Flow

Open channels are assumed to begin where field surveyed cross section channel information has been obtained, where channels are visible on meter, Average flow velocity is usually determined manning's equation information can be used to estimate average flow velocity.

When the channel section and roughness coefficient (Manning's n) are available, then the velocity can be computed using the Manning Equation

$$V = (R^{2/3}S^{1/2})/n$$ ……3.18

Where: V= average velocity, m/s

R= hydraulic radius, m (equal to a/pw)

A = cross sectional flow area, m

Pw = wetted perimeter,

S = slope of the hydraulic grade line, m/m

n = Manning's roughness coefficient

$$T_t= \frac{L}{!3600V}+\cdots$$ ……3.19

Where=Tt = travel time, hr, L = flow length, m, V = average velocity, m/s and 3600 = conversion factor from seconds to hours. the basin and the outlet.

The time of concentration is the sum of Tt values for the various consecutive flow segments

Tc=Tt1+Tt2+Tt3……3.20

3.7. The Use of Bentley Civil Storm V8i Software

3.7.1. Software Description

The Bentley civil Storm V8i dynamic stormwater modeling engine calculates runoff volume and analyzes the hydraulic response through dependent systems of inlets, pipes, channels, manhole, outlet, ponds. It is tools that make it easy to visualize flooding problems and how they can be eliminated. Animate profiles, plan views, and other presentations to observe water levels rising and falling over the course of a storm data (Bentley, 2014).

Bentley civil Storm V8i features: -

A. Dynamic integration of rainfall, runoff, surface flow, storm sewers, open channels, culverts, and ponds
B. Looped systems with diversions
C. Pressure and gravity profiles
D. Complex pond outlet structures
E. Capture and carryover between inlets
F. Hydraulic grade profile animation
G. Customizable presentations and graphs

Civil Storm V8i is an extremely efficient tool for laying out a storm sewer network. It is easy to prepare a schematic or scaled model A schematic drawing is one in which pipe lengths are entered manually, in the user-defined length field (Bentley, 2014).

3.7.2. Steps in Using Bentley Civil Storm V8i

The following steps generally used for selected study area: -

1.Specify a default set of options and object properties to use

A. Default Id labels for Sub- Catchment, Manhole, Conduit and Outlet
B. Default sub-catchments properties like area
C. Default Manhole/Conduit properties (node invert, conduit length, routing method)

2. Draw a network representation of the physical components of the study area

A. Adding a Rain fall intensity in 25 years in global storm event of study area
B. Adding a Sub-catchment (from delineated watershed catchments) of a town
C. Adding a Manholes of study area
D. Adding a conduit (pipes connecting Manholes of study area)
E. Adding a outfall of study area

3.Edit the properties of the objects that make up the stormwater drainage system

A. Data entry a sub –catchment

B. Data entry a manhole

C. Data entry a conduit

D. Data entry a outfall

4. Select a set of analysis options.

5. compute the stormwater drainage network system.

6. View the results of the study area simulation.

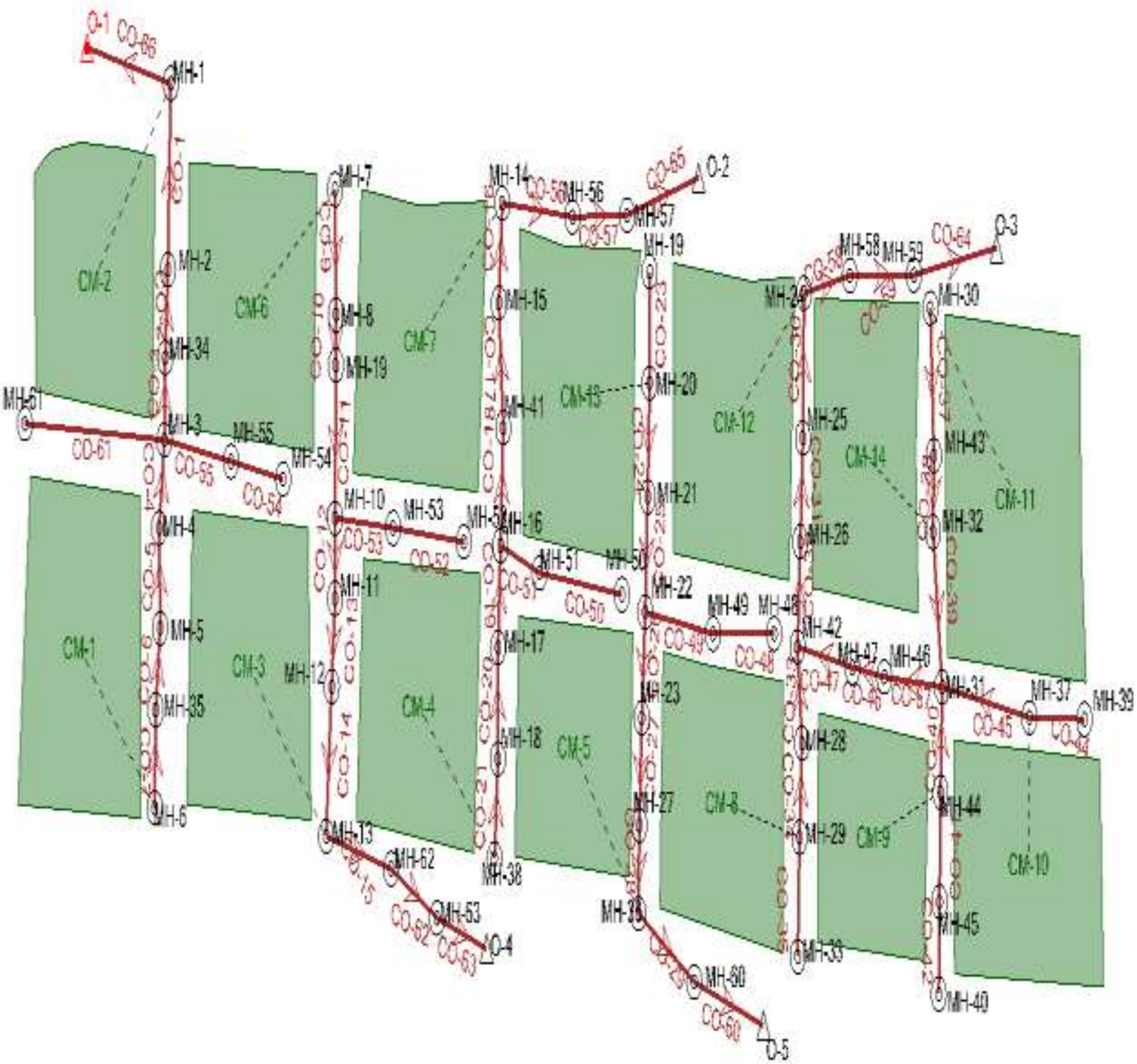

Figure 3.3. Storm Sewer network projected for 25 year

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Impact of land use land cover change on storm water runoff with in the

The output images of land use land cover and analysis was presented in this section. The land use land cover images developed for the years 1986, 2010 and 2017 by using Arc- GIS.10.4.1. and for each land use and land cover, annual storm water run-off volume was calculated.

Table 4.1. Estimated annual runoff from land use land cover map in 1986 year.

Lulc map of town	Runoff coefficient	Areal rainfall (m)	Area($m^{2)}$	volume runoff (cu.m)
Built -up Area	0.8	1.465	5490000	64342800
Agricultural	0.2	1.465	3737700	109151461
Vegetation	0.25	1.465	3165300	11592911.25
Bare Land	0.48	1.465	900	6328.8
Water Body	0.5	1.465	15300	112072.5

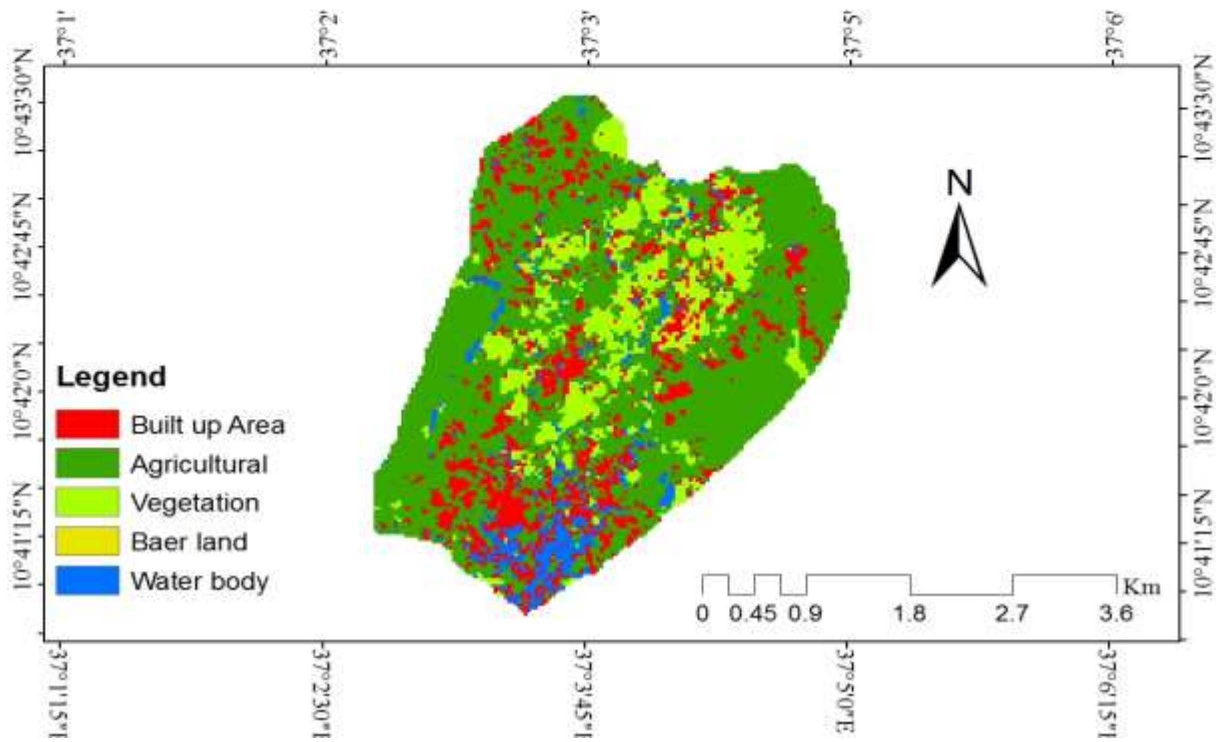

Figure 4.1. Land use land cover maps of Bure town catchment in 1986

Table 4.2. Estimated annual runoff from land use land cover map of 2010 year

Lulc	Runoff coefficient	Areal rainfall in (m)	Area (m^2)	volume runoff(cu.m)
Built -up Area	0.8	1.465	6680000	7828960
Agricultural	0.2	1.465	2976298	872055.314
Vegetation	0.25	1.465	2561402	938113.4825
Bare Land	0.48	1.465	177100	124536.72
Water Body	0.5	1.465	14400	10548

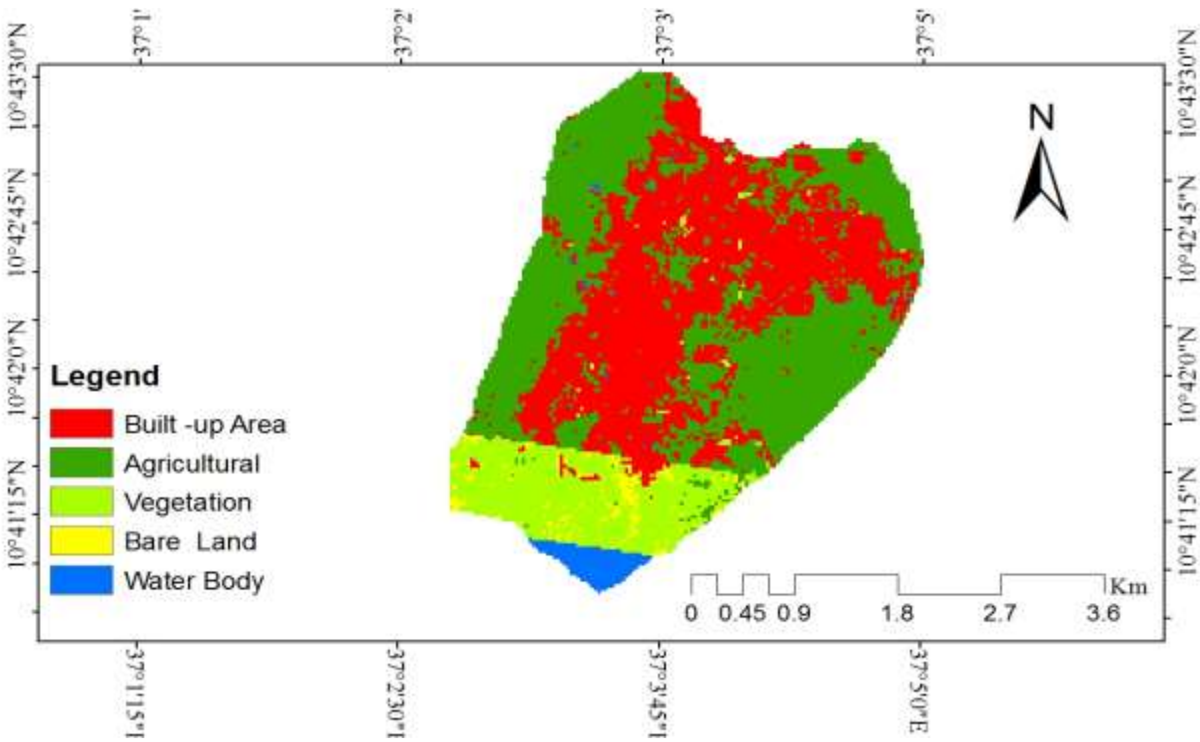

Figure 4.2. Land use land cover maps of Bure town catchment in 2010

Table 4.3. Estimated annual runoff from land use land cover map of 2017 year

Lulc	Runoff coefficient	Areal rainfall in (m)	Area(m^2)	volume runoff (cu.m)
Built -up Area	0.8	1.465	7747100	9079601.2
Agricultural	0.2	1.465	2579588	755819.284
Vegetation	0.25	1.465	1861284	749325.89
Bare Land	0.48	1.465	208478	16750.92
Water Body	0.5	1.465	12750	9339.37

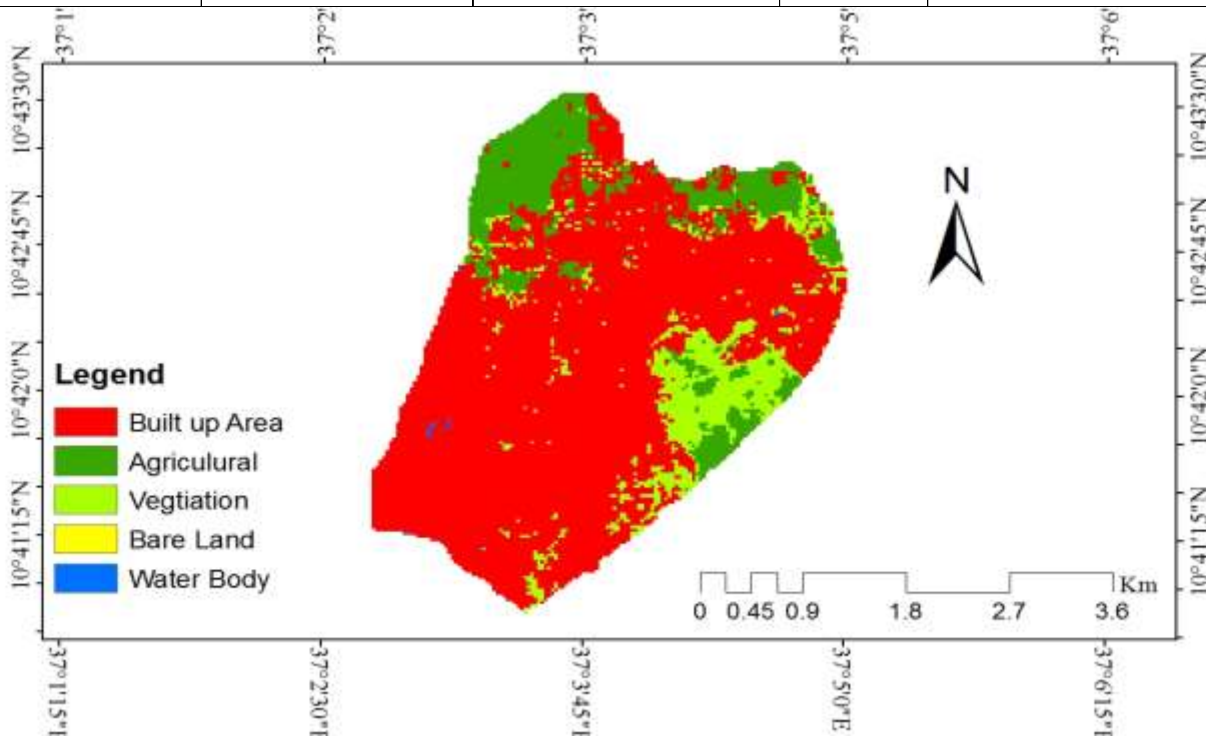

Figure 4.3. Land use land cover maps of Bure town catchment in 2017

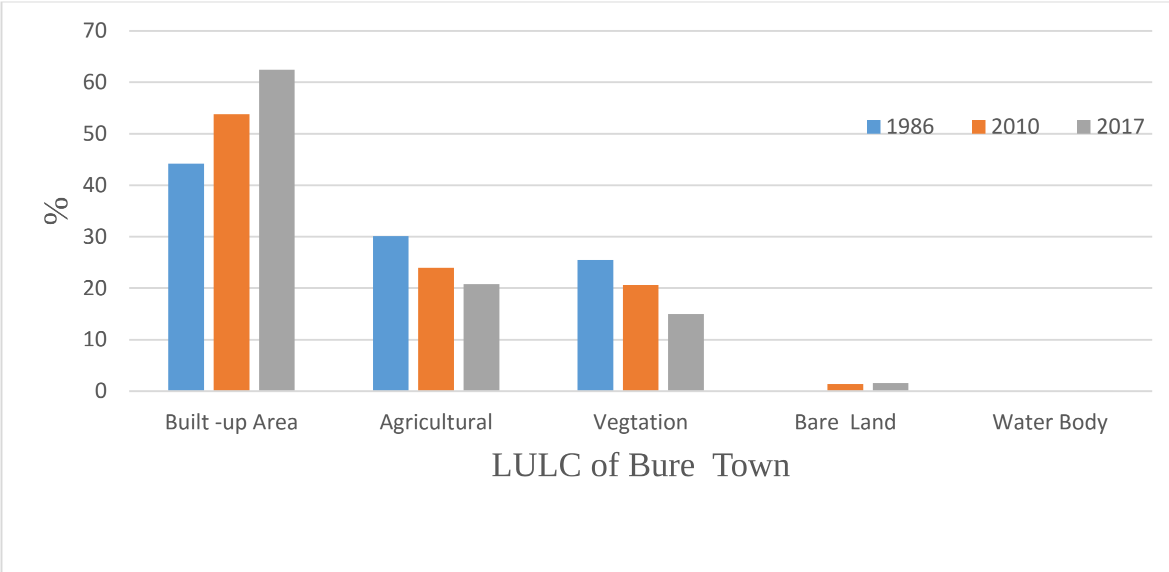

Figure 4.4. Land use land cover changes of Bure drainage area in 1986-2017 year.

Table.4.4. The impact of change land use land cover between 1986 and 2010

Lulc	Runoff coefficient	Areal rainfall in (m)	Area(m^2)	volume runoff(cu.m)
Built -up Area	0.8	1.465	1190000	1394680
Agricultural	0.2	1.465	-761402	-223090.8
Vegetation	0.25	1.465	-603898	-221177.5
Bare Land	0.48	1.465	176200	123903.8
Water Body	0.5	1.465	-900	-659.25

Table.4. 5. The impact of Change land use land cover between 1986 and 2017

Lulc	runoff coefficient	Areal rainfall in (m)	Area (m^2)	volume runoff(cu.m)
Built -up Area	0.8	1.465	2257100	2645321.2
Agricultural	0.2	1.465	-1158112	-339326.8
vegetation	0.25	1.465	-1304016	-477595.86
Bare Land	0.48	1.465	207578	145968.8
Water Body	0.5	1.465	-2550	-1867.875

Figure 4.5: Annual runoff comparison: Post vs Pre-development.

The results indicate that densely developed which has resulted in decrease of agricultural, water and vegetation regions. The continuous change of barren land and built-up region has affected agricultural, water and vegetation regions. This is very much evident from the table 4.4 and table 4.5 depicting the overall trend in the land use / land covers change for the period of 1986 to 2010 for pre development and 1986 to 2017 for post development results revealed both increase and decrease volume runoff of the different LULC classes from 1986 through to 2017. With urban expansion and development, more of the natural landform will be converted into impervious surface. This significant shifts from some classes to others was also observed. Drivers of the observed changes might be climatic factors such as rainfall and drought to socio-economic factors and also the city is in the stage of rapid urbanization and with it, a rapid increase in built-up spaces.

4.2. Hydrology and Hydraulics Analysis

4.2.1. Hydrologic Analysis

Hydrologic analyses, the following factors should be evaluated and included when they will have a significant effect on the final results: Drainage basin characteristics including: size, land cover, land use, Stream channel characteristics natural and artificial controls, Flood risk, meteorological characteristics such as precipitation amount rainfall intensity and pattern, areal distribution of rainfall over the basin, and duration of the storm event.

4.2.1.1. Results Using Rational Formula

As indicated in below table 4.6 the discharge calculated by this method for area less than 0.5km2. The parameters involved in this calculation were run-off coefficient from Land use composition of the study area (the runoff coefficient is determined due to land use and land cover change), rainfall intensity reading from time concentration and return is specified for IDF curve which developed for Bure town. The calculated rainfall intensity is indicated in appendix. Return period is fixed based long time strategic plane. The recurrence design frequency 25 years for a long-range strategy plan for the entire urban region. Therefore, this research used 25 years' design storm frequency for urban area.

Using the daily maximum rainfall from metrological agency, 24-hour design rainfall was calculated using Log Pearson type III distribution methods. The values are compared with Ethiopian Roads Authority recommended values and the maximum was taken, as it is recommended by ERA. The rainfall of ERA is attached on the appendix part.

Land use composition of the in Bure town the total area is 1240 ha. The runoff coefficient taking the average land use land cover in 2017 using the above formula is 0.58 in equation 3.12 and to used overall the catchment because due to improper land use map of Bure town.

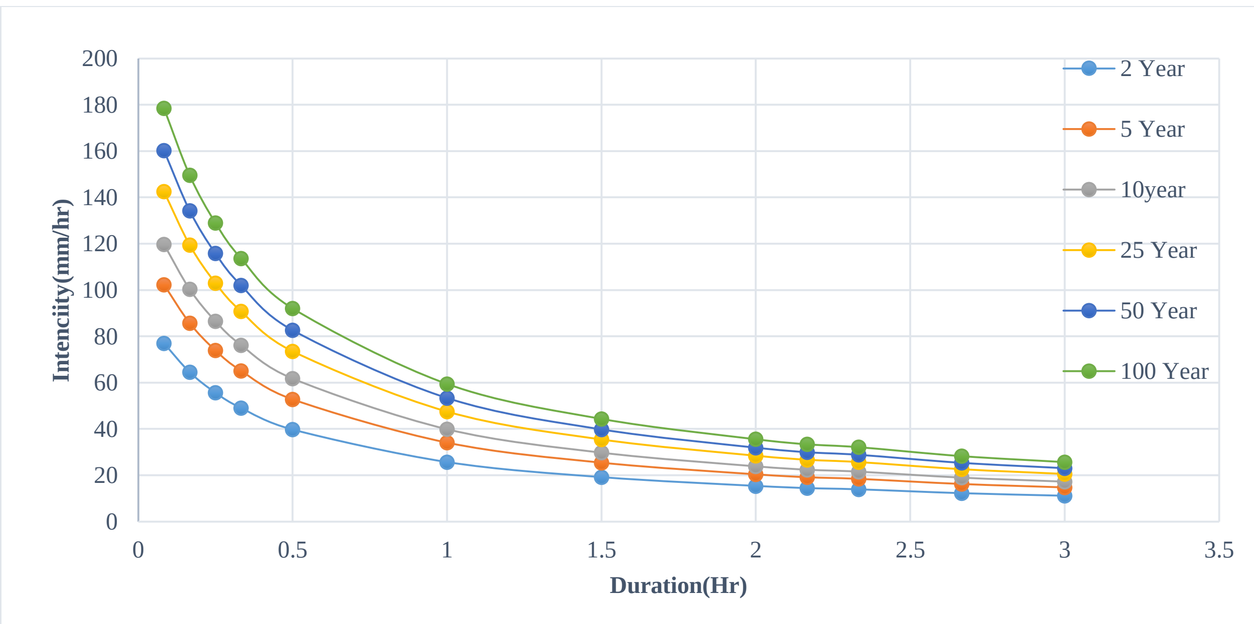

Figure 4.6. Intensity Duration-Frequency curve of Bure town

Peak discharge is calculated using equation (3.11).

Table 4.6. Peak catchment runoff results

Sub- catchment	Area(Ha)	Total Tc(Hr.)	IDF(for 25 year frequency)(mm/hr.)	Runoff Coefficient	Discharge(m^2/s)
CM-1	35.35	1.25	41.80	0.58	2.38
CM-2	40.00	1.07	42.90	0.58	2.77
CM-3	49.80	1.37	39.52	0.58	3.17
CM-4	34.00	1.35	40.10	0.58	2.20
CM-5	48.70	0.69	54.00	0.58	4.24
CM-6	48.40	1.05	43.60	0.58	3.40
CM-7	30.70	0.62	60.00	0.58	2.97
CM-8	48.32	0.46	84.00	0.58	6.54
CM-9	49.90	0.53	70.00	0.58	5.63
CM-10	48.90	0.29	101.30	0.58	7.99
CM-11	49.41	0.71	49.20	0.58	3.92
CM-12	47.60	0.55	65.00	0.58	4.99
CM-13	49.80	0.85	48.50	0.58	3.89
CM-14	46.58	1.48	37.25	0.58	2.80

4.2.2. Hydraulic Analysis

The current condition hydraulic performed calculation is by collected the existing storm water drainage structure by using field serving. The following are record data based on the geometry of the channel these are width and depth by using tape meter measurement and slope from topographic map of town. The shape of cross sectional existing condition of stormwater drainage in Bure town is rectangular channel (Side slop: 1V:1H) and the manning coefficient is the roughness of the material take from (FHWA, 2014) .Manning's roughness coefficient of concrete (n = 0.013).

Table 4.7. Existing condition Bure town in hydraulic elements result

Sub catchment	Slope(%)	Depth(m)	Width(m)	Manning coefficient	R(m)	V(m/s)	Discharge(m^3/s)
CM-1	0.01	0.50	1.30	0.013	0.42	1.60	1.84
CM-2	0.01	0.40	1.25	0.013	0.30	2.67	2.59
CM-3	0.01	0.60	1.30	0.013	0.50	1.87	2.81
CM-4	0.01	0.40	0.60	0.013	0.32	3.91	2.19
CM-5	0.01	0.45	0.70	0.013	0.37	1.87	2.71
CM-6	0.02	0.50	0.60	0.013	0.40	2.14	2.87
CM-7	0.01	0.45	0.60	0.013	0.36	3.69	2.49
CM-8	0.03	0.60	0.90	0.013	0.49	2.67	3.36
CM-9	0.04	0.30	0.70	0.013	0.25	5.45	2.13
CM-10	0.01	0.30	0.50	0.013	0.24	2.73	0.90
CM-11	0.01	0.40	0.70	0.013	0.33	1.58	2.56
CM-12	0.02	0.50	1.30	0.013	0.42	2.19	2.52
CM-13	0.02	0.65	1.21	0.013	0.54	2.24	3.64
CM-14	0.01	0.50	0.90	0.013	0.41	1.53	2.53

Table 4.8. Existing and Rational method of discharge resulted.

Sub catchment	Existing condition Discharge(m^3/s) of Town	Rational method Discharged(m^3/s) ERA
CM-1	1.84	2.38
CM-2	2.59	2.77
CM-3	2.81	3.17
CM-4	2.19	2.20
CM-5	2.71	4.24
CM-6	2.87	3.40
CM-7	2.49	2.97
CM-8	3.36	6.54
CM-9	2.13	5.63
CM-10	0.90	7.99
CM-11	2.56	3.92
CM-12	2.52	4.99
CM-13	3.64	3.89
CM-14	2.53	2.80

The diameter of storm water drainage determination for existing condition and rational method discharge. Manning equation was used to determine the size of drainage system in the as appendix each catchment diameter for rational method and existing conation of drainage system.

4.2.2.1. Flooding occurrence of stormwater drainage system

The Bure town manhole flood occuring due to small sizes, numbers of conduits limted and maximumme runoff of catchment out flow occurancs of flooding problem for the following situation to be seen on the outfall location 1 and 3.

1. The flooding occurrences of catchments is CM8, CM9, CM10, CM-11, CM-12 and CM-14, the size of drainage is small of maximum discharge capacity for manholes is MH-24, MH-25, MH-26 MH-28, MH-29, MH-30, MH-31, MH-32, MH-37, MH-42, MH-43, MH-44, MH-46, MH-47, MH-58, MH-59 and conduits of MH-40 to MH-31, MH-30 to MH-31, MH 39 to MH-42 and MH-33 to O3 in out let 3.
2. The flooding occurancs of catchments is CM-1 and CM-2 , the size of drainage is small of maximum discharge capacity for manholes is MH-5, MH-6, MH-35 and conduit of MH6 to O1 in outlet 1.

Table 4.9. Flood risk manhole of stormwater drainage system

ID	Label	Flood risk in manhole (m^3/s)
55	MH-5	2.5
56	MH-6	2.52
78	MH-24	14.03
79	MH-25	14.58
80	MH-26	14.58
84	MH-28	5.41
85	MH-29	5.41
86	MH-30	5.41
87	MH-31	11.68
88	MH-32	5.75
95	MH-35	2.52
99	MH-37	4.25
117	MH-42	14.58
118	MH-43	2.96
119	MH-44	5.91
130	MH-46	11.68
131	MH-47	11.68
143	MH-58	14.03
144	MH-59	14.03

Generaly the hydraulic condition in the stormwater drainage is the overcharged-flow- resulted street surface flooding. This condition in which the drainage flow into the sewer pipe is much larger than the sewer capacity .In addition, at the sewer (manholes) where there may be open access to the ground, the flow starts to go upward through the manhole openings and overtop the manhole rims. In this study the impact of flooding problem of storm water drainage system and the capacity of manhole as a function the geometry of conduit and outfall. The Bentley CivilStorm to show hydraulic grade and energy profile for storm water drainage system of town to identification which flooding risk of manhole , cause of catchment , conduit and out fall of Bure town due to the effect of pipe failure and sediment deposition of stormwater drainage system.

Obvert of drainage layout

Figure 4.7: The water flow from starting Manhole -6 to Out let- 1

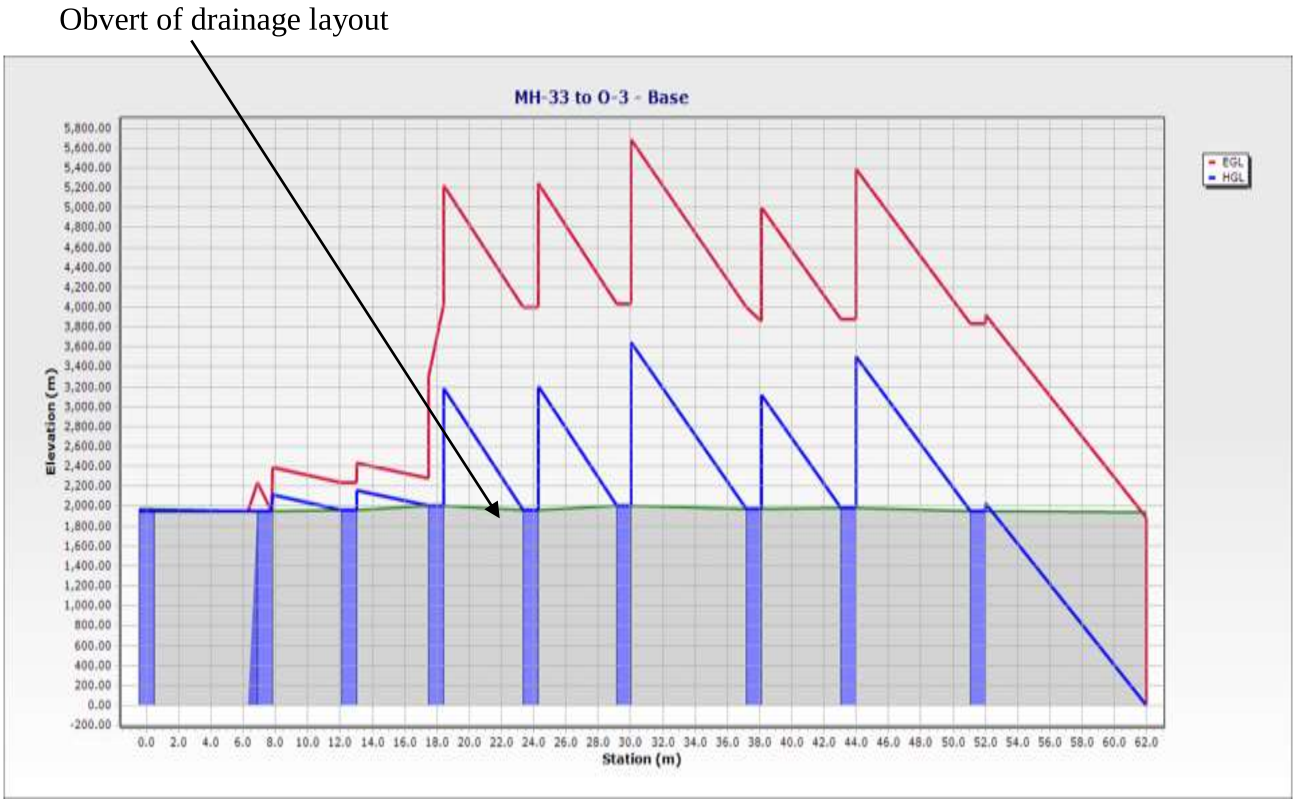

Figure 4.8: The water flow from starting Manhole -33 to Out let- 3

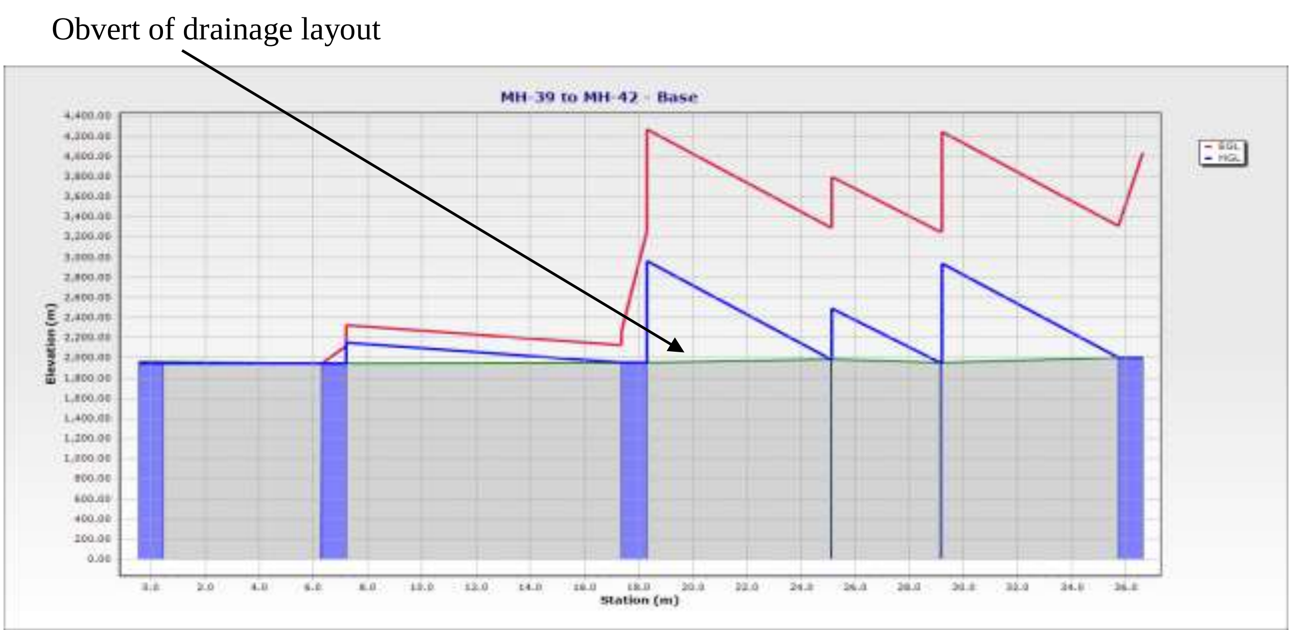

Figure 4.9: The water flow from starting Manhole -39 to Manhole -42 into Out let- 3

Obvert of drainage layout

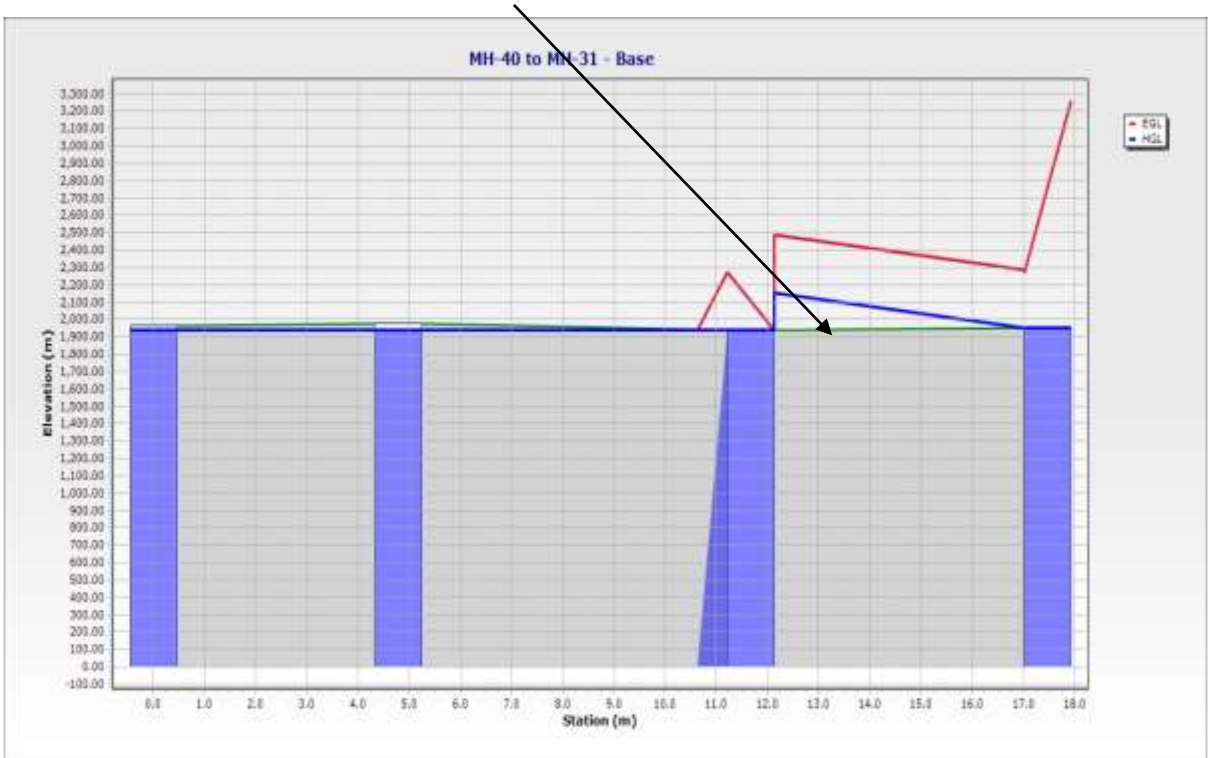

Figure 4.10: The water flow from starting Manhole -40 to Manhole -31 into Out let- 3

Obvert of drainage layout

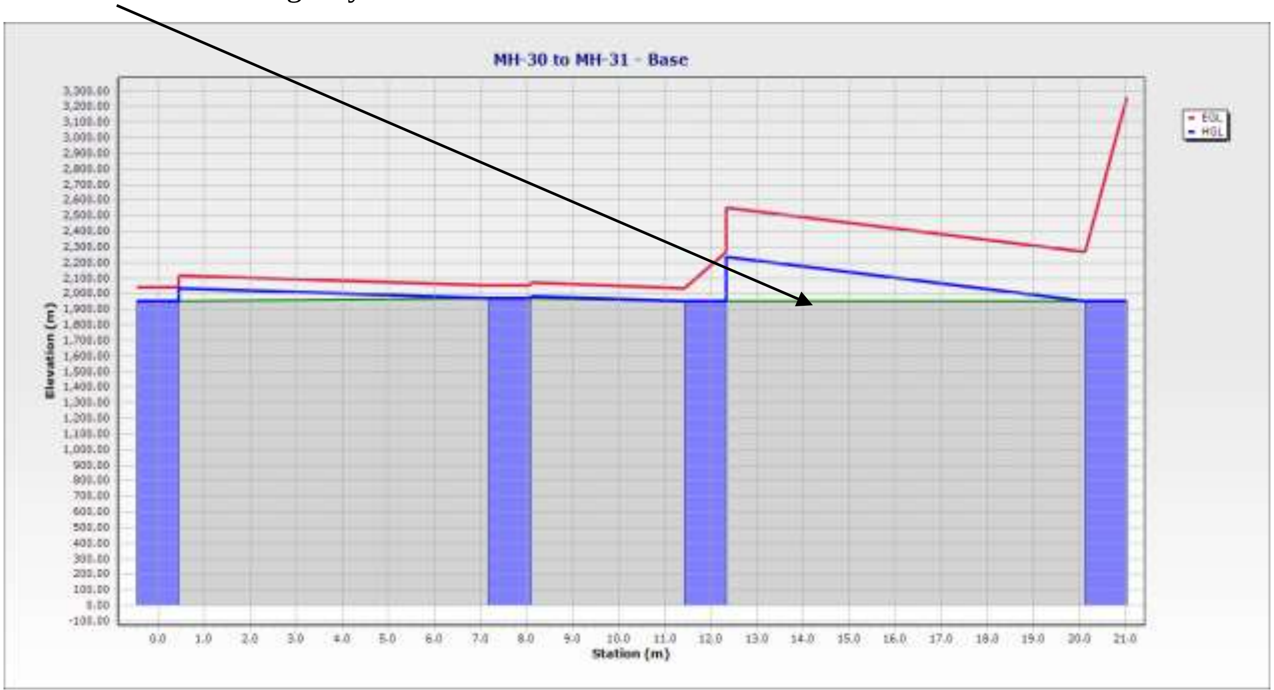

Figure 4.11: The water flow from starting Manhole -30 to Manhole -31 into Out let- 3

The form of HGL is a series of downward sloping lines over pipe length with steeper or vertical drops at manholes. The level and grade of HGL varies depending up on flow. Higher flows result in higher surfaces run off and consequently steeper grade on HGL. A HGL plotted on drainage profile should corresponding to the analysis for pipe system. If HGL is at the obvert of pipe, the pipe s considered to be running full and the higher HGL is above the obvert of a pipe ditch considered to be pressure of maximum flow condition for outlet (Institute of enginerr Australia, 2001).The Bure town storm water drainage system in the above figure 4.7 is the HGl is above the obvert of drainage layout maximum flood condition for outlet one, But at middle point the drainage network capacity full condition is occurred and also figure 4.8, figure 4.9, figure 4.10 and figure 4.11 is the HGl is the beginning of at the obvert of drainage layout the capacity of drainage full condition occurred and after this full condition drainage layout increasing or decreasing HGL with respect to flood condition going to the outlet three due to limitation of the size of drain and topography of a town .

Figure 4.12: The water flow from starting Manhole -38 to Out let- 2

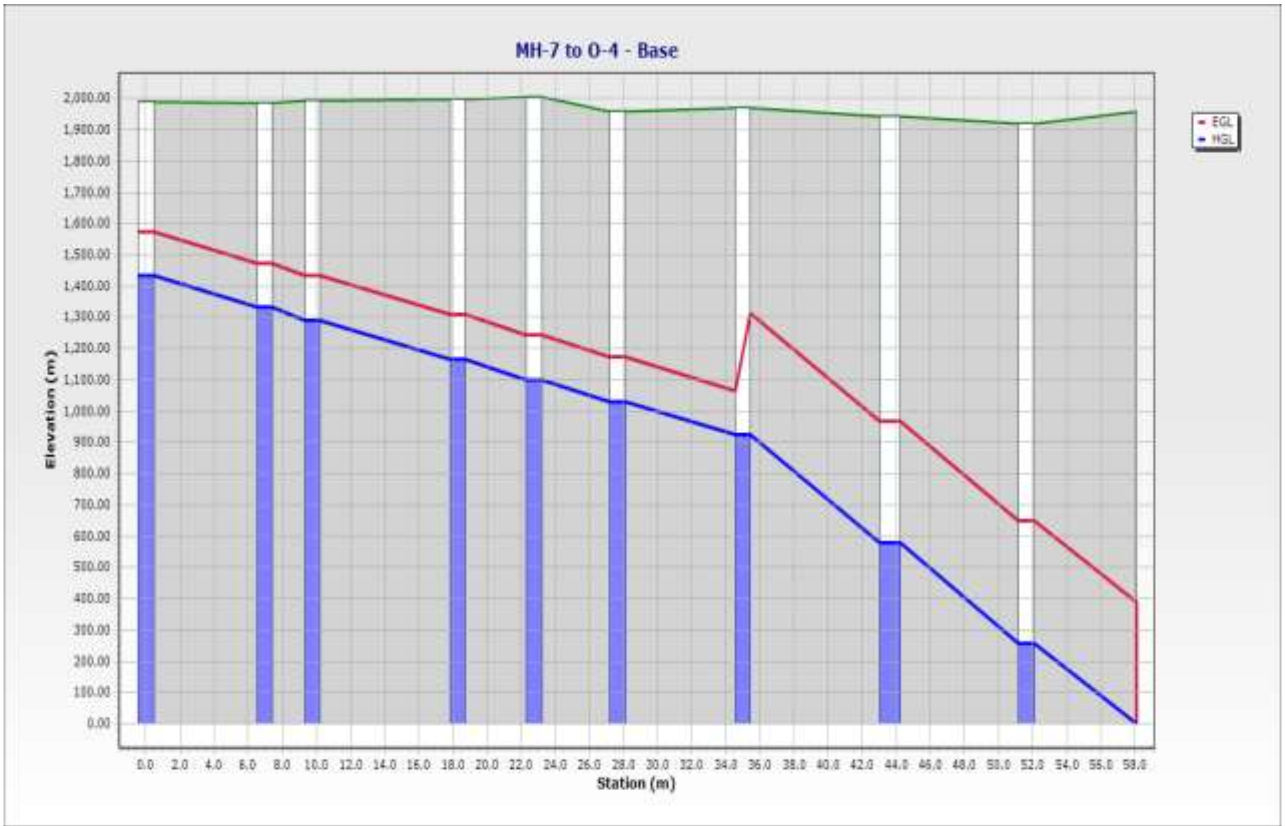

Figure 4.13: The water flow from starting Manhole -7 to Out let- 4

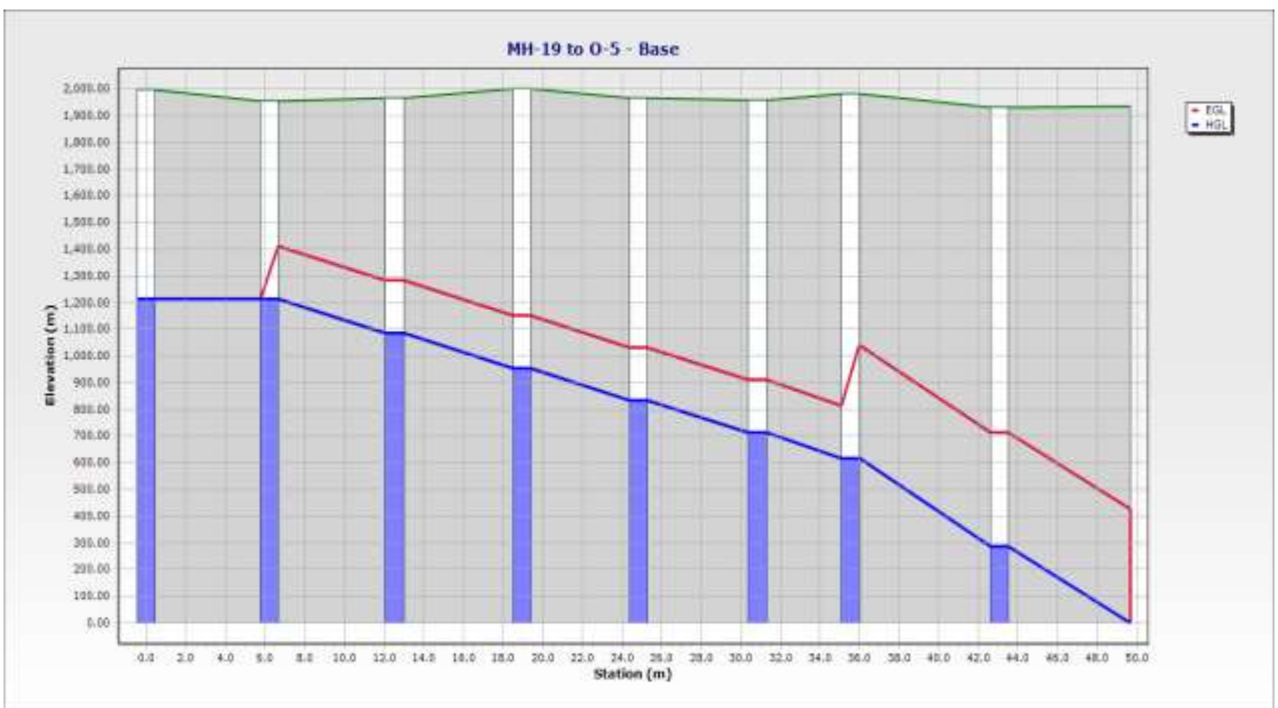

Figure 4.14: The water flow from starting Manhole -19 to Out let- 5

When it comes to urban flooding, two important hydraulic concepts a rise surcharge and backflow. A drainage system is surcharged when its capacity is exceeded, i.e. it receives greater volume of water than the system can convey. As a result, the water level rises upstream due to the network overloading and if the energy line reaches higher points downstream than upstream, water may change the regular flow direction leading to backflow (Butler and Davie , 2004). In the above figure 4.12, figure 4.13 and figure 4.14 it is the connivance problem and water logging occurred in Bure town stormwater drainage system. Since the water level (hydraulic grade line) of upstream a rise than downstream caused conduit problem and the energy grade line downstream a rise than upstream that caused by waterlogging of drainage system. So the Bure town streets and drainage system unsafe that causes problem of welfare, unprotection of traffic safety, inadequate movement of traffic and increasing potential of public health risks associated with stormwater systems.

4.3. Challenges of Storm Water Drainage in the Study Area

Apart from significant flood regime change, field visits and survey reveals that there are different challenges which makes the process of disposing runoff in to water ways made difficult in this area. The challenges are:

4.3.1. Dumping of solid wastes in to storm water drainages system

Dumping solid waste materials in to drainages is the challenge of storm water drainage system. Urban litter (alternatively called trash, waste, garbage, or solid waste) has become a major problem's as result of damping these solid wastes in to drains the drainage system has been clogged and causes flooding over streets and walk ways. Respondents Monitoring Survey (2017) about the solid waste in the City is disposed: shortage of disposing area 37.5%, lack of awareness 32.5% and carelessness 30% for storm water drains system. In this result indicated that the Bure town blockage of drainage system by the solid waste, poor maintenance practice of drainage system and lack strong integration among stakeholders in the provision of drainage infrastructure to ensure sustainability of drainage system. Within the town municipality weak technical capacities associated solid wastes disposal system because lack budget, lack of integration among governmental origination with in community and shortage of community participation are factors to difficult proper sustainability drainage system.

Figure 4.15. Dumping of solid waste in Bure town (Fieldwork ,2017)

4.3.2. Lack of cleaning stormwater drainage system

Concerning drainage infrastructure provision the main problems associated are like poor coordination and integration among stakeholders. Moreover, community participation is among the lowest in the study area. In the study area 32 out of 40 respondents or (80%) of respondents proved that there is no community participation in one way or another for drainage infrastructure provision.

Due to lack of f clearance stormwater drainage lines they have become out of services. Sediment load, solid wastes blocked most of the drainage system. So without scheduled clearance the service life of those ditches and channels could be out of their life span. Figure 4.16. Shows blocked sediments ditches in Keble 1.

Figure 4.16 Blocked drainage network by sediment loading in Bure town (Fieldwork ,2017).

4.3.3. Urban Population in SWDM

The base population for the projection was obtained from the 2007 Population and Housing Census Bure town and adjusted to the mid of the census year (FDROECSA, 2014).

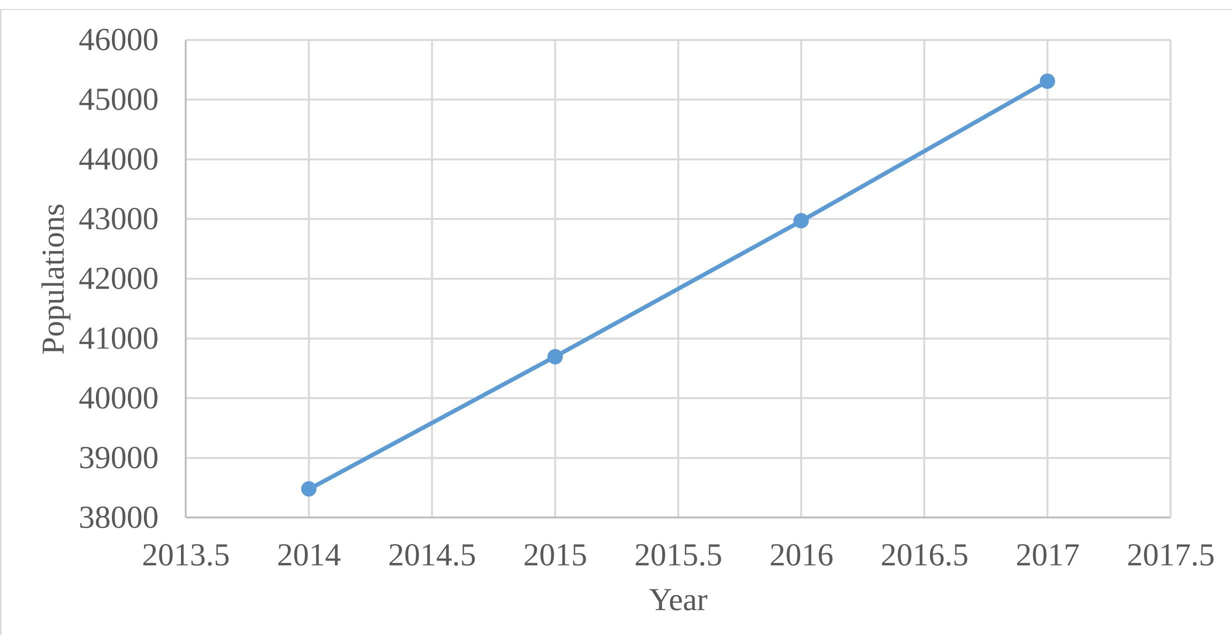

Figure 4.17. Bure Town Population Projection

Respondents were asked to report on the challenge of urban Population on stormwater management as regards to increasing of surface runoff. From the results obtained Forty-Five percent (45%) reported that it led to increasing flooding, Thirty-Seven percent (37% resulted to unsustainably use stormwater drainage facilities, fifteen percent (15%) of the respondents reported that of urban Population lead to increasing flooding risks and tow percent (2%) indicated that urban Population lead to don't know/No response.

As population grows, demand for housing and commercial amenities naturally follows. The urbanization adds roads, rooftops, parking lots, sidewalks, and other imperviousness to the landscape (Moglen, 2007). Therefore, the Bure town population rapidly increasing from time to time to grate impact increasing surface runoff.

Table 4.10. Challenge of urban population on Storm water management

Urban population on storm water Management	No questionnaires received	Percentages(%)
Increasing surface runoff	18	45%
unsustainably use of drainage facilities	15	37.5%
Increasing flooding risks	6	15%
Don't know/No response	1	2.5%
Total	40	100%

(Source: field survey)

The results of this survey indicate that Urban population greatly affect storm water management in increasing flooding in Bure town. Urban conditions made worse drainage problems; runoff is increased by impermeable urban surfaces, residential area, commercial area, street, paved road and due to inadequate development control mechanisms and their incompetent enforcement, settlements are constructed with little consideration for storm water drainage system.

4.3.4. Type of Existing Drainage System of the town

To find out the existing drainage system condition by using the photographic technique and questioner to ensure performance level such as excellent, very good, good, average, and poor conditions.

Table 4.11. Respondents response on the type of existing conditions of drainage system

	Excellent	Very good	Good	Poor	Total
No		1	8	31	40
%		2.5	20	77.5	100

(Source: field survey)

Based on field survey data 77.5% of the respondents claimed that the existing condition of the drainage system is poor and unable to perform their intended purpose, and 20 % of them said that the drainage infrastructures of the town are at a good condition, whereas 2.5% were responded that the drainage system is at very good condition. In general, the existing drains in the city are not well planned, road did not function properly due sedimentations and debris, flooding occurrences, bad smell and transmitting of water born disease.

The main challenges of the Existing drainage network Condition are visited: -

A. Drainage systems are not well connected in to outfall;
B. Drainage systems are doing not have the capacity to carry large amounts of water, hence resulting in overflowing;
C. Ponds or other spaces are not properly allocated to accommodate overflow of flooding;
D. Most ditches do not have proper slope to let water pass through them;
E. In some areas there are no drainage systems provided at all
F. Some of existing drainage ditches have been silted by sand and other rubbish materials
G. flooding or inundation and Sedimentation stagnation of water
H. Damage to properties like existing drainage facilities and buildings or houses.

Figure 4.18. Improper drainage size ditch along the main road flooding (Fieldwork ,2017)

Figure 4.19: Open storm drainage system and improper slope (Fieldwork ,2017).

4.3.5. Assessing of Flooding and Crack Bure Town Street at the Study Area

Currently, road flooding and its related effects are common in Bure town. Most of the drains are in poor condition for proper functioning. Brasted roads have their own challenge over the drainage systems because their damaged surface couldn't convey the runoff generated over the impervious area.

Table 4.12. Major flood prone areas in the study area

specific site/Keble	respondents		Ranking of flood prone area (high to low) field survey
	Number	Percentage	
kebel1	15	37.5	2nd
kebel2	18	45	1st
kebel4	7	17.5	3rd
Total	40	100	

(Source: field survey)

This problem implies that flooding has been noticed in most of Keble 2 suburban roads due to:

A. Inadequate integration between road and urban storm water drainage lines
B. Inadequate drains are that causes of flooding in the study area,
C. Does not carrying capacity drainage system for problem of solid waste dumping increasing with Sewerage connection
D. Urban storm water drainage facilities not welled constructed with roads safely discharge to flood generated within the study area of storm water drainage facilities which is the challenge for the town.

Table 4.13. The major causes of flooding.

No	Major causes	Respondents	
		Number	Percentage
1	Blockage of drains by solid wastes	14	35
2	Inadequate drains	17	42.5
3	Absence of drains	8	20
4	Other	1	2.5

(Source: field survey)

Figure 4.20. Crack road in Bure town street in Keble 2 (Fieldwork ,2017)

Figure 4.21.Rotten egg in community solid waste disposal respondent environment (Fieldwork ,2017).

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

According to the findings land cover/land use practices in the study area of stormwater runoff have significantly changed in 31 years. The LULC shift in the effects of urban expansion watershed area was evident by the decline in the area of Agriculture, Vegetation and Water body class 1986 to 2010 and 1986 to 2017, but in the area of built up and bare land increasing is mainly due to urbanization. So, the built up and bear land of watershed region volume of runoff is significantly increased from (1394680cu.m and 123903.8 cu, m) of pre development to (2645321. 2cu.m and 145968. 8 cu.m) of post development respectively due to increased development of town can have the impact of hydrology. The continuous increasing of barren land and built-up region are affected of agricultural, vegetation and water body class due to lack of land use planning, socioeconomic activities, natural phenomena and the challenge of stormwater runoff control for pre development and of post development of Bure town.

As seen from the modeling results, the hydraulic condition in the stormwater drainage system is the overcharged-flow- resulted street surface flooding from in (CM-8, CM-9, CM-10, CM-11, CM-12, CM-14, CM-1, CM-2, MH-5, MH-6, MH-24, MH-25, MH-26 MH-28, MH-29, MH-30, MH-31, MH-32, MH-35, MH-37, MH-42, MH-43, MH-44, MH-46, MH-47, MH-58, MH-59 and conduits of MH-40 to MH-31, MH-30 to MH-31, MH 39 to MH-42 and MH-33 to O3 in out let 3, and conduit of MH-6 to O1 in outlet 1). This is the condition in which the drainage flow into the sewer pipe is much larger than the sewer capacity. In this study to obtain the understanding of flooding risk of storm water drainage system will be seen due to the lack of proper drainage infrastructures, drainage connivance, limitation of the size of drain and topography of a town there by resulting damages road surfacing and flooding problems in the area. The Bure town streets and drainage system unsafe that causes problem of welfare, unprotect ion of traffic safety, inadequate movement of traffic and increasing potential of public health risks associated with stormwater systems.

The problem as was established through this study is the drainage system that is not adequate. Going by the responses from Bure town municipality, civil servant, governmental and none governmental organization and residents, the problem lies in the drainage system. There was a general feeling that the type of drainage system is not adequate. Therefore, need for immediate remedies in order to achieve a good drainage system. As it was observed during field survey the findings of challenge of stormwater management in Bure town the existing drains are not maintained properly, awareness at the community level of drainage system by municipality is poor since some people are intension of throwing solid waste into existing drains that caused flooding .The sewerage connection filling by solid waste dumping to reduce the effective carrying capacity of drain.

5.2. RECOMMENDATIONS

Based on the finding of the research the following recommendations: -

1. Adjusting hydrologic and hydraulic analysis for future change situations is very important in order to ensure safe drainage structures function in the long-term perspective. In this, it is essential that the Ethiopian Road Authority understands the required adaptation process and Common causes of damage to drainage and existing problems in drainage systems should be identified early during planning.
2. I recommended that future studies related with urban drainage flooding and analysis stormwater drainage system Bentley Civil Storm model8 vi to be used and Increase the sizes to stop flooding of manholes.
3. Proper land use planning should be done for the watershed prior to any developmental project being conducted in the area
4. There is no organized data regarding stormwater drainage structures in Ethiopia which is essential to investigate the structure in detail. Therefore, data should be organized.
5. The application of GIS to study urban hydrology for determining for better and timely estimates of runoff within drainage basin, potentially reducing loss of life and damage to the property caused by unusual weather events
6. At CM-1, CM-2, CM-8, CM-9, CM-10, CM-11, CM-12 and CM-14 is runoff contribution for the town, so therefore to avoid this problem should be BMP recommended.

7. During summer season flooding occurrence. I recommend that to use more of the rainwater harvesting technique can be used to meet the water demand as well as for reducing water volume, sent to drain. There can also be a possibility of recharge pits so that rain water is sent directly to underground level rather than to drain channels. People should be encouraged to have more of the natural landscape, wherever possible to minimize watertight surface for catchment there reuse water for community.
8. Increase tree cover in Bure town area especially the neighboring hills, with appropriate tree species including planting of agro-forestry tree species to avoid erosion.
9. Improve the drainage systems along the Bure town highways, Redesign stormwater drainage system and Improvement of drainage facilities through maintenance.
10. The rate and density of urban development is controlled and mitigated in the future, water quality can be protected and impacts from increased runoff can be reduce.
11. Finally, for community creates awareness concerned the effects of disposing solid materials in to drainage facility by the municipality and other concerned body.

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Appendixes

Appendix 1: Design rainfall, frequency, IDF curve and 24-hr Rainfall depth

Table 1.1 Max rainfall data from 1985-2016 and its statistical calculation

No	Year	Max Rainfall	Descending Order	Rank	Log(Y)	New mean Rf	log(x)
1	1985	69.4	179	1	2.252853031	98	1.991226076
2	1986	64	98	2	1.991226076	72.4	1.859738566
3	1987	46.5	72.4	3	1.859738566	69.4	1.84135947
4	1988	53.1	69.4	4	1.84135947	65.7	1.81756537
5	1989	98.1	65.7	5	1.81756537	64	1.806179974
6	1990	61.4	64	6	1.806179974	61.4	1.788168371
7	1991	47.55	61.4	7	1.788168371	60.8	1.783903579
8	1992	37.2	60.8	8	1.783903579	60.1	1.778874472
9	1993	35.9	60.1	9	1.778874472	57.7	1.761175813
10	1994	52.3	57.7	10	1.761175813	53.1	1.725094521
11	1995	65.7	53.1	11	1.725094521	52.3	1.718501689
12	1996	60.8	52.3	12	1.718501689	51.4	1.710963119
13	1997	34.8	51.4	13	1.710963119	47.55	1.677150521
14	1998	24.8	47.55	14	1.677150521	47.2	1.673941999
15	1999	36.35	47.2	15	1.673941999	46.5	1.667452953
16	2000	35.95	46.5	16	1.667452953	43.2	1.635483747
17	2001	29.6	43.2	17	1.635483747	42.5	1.62838893
18	2002	35.65	42.5	18	1.62838893	40.5	1.607455023
19	2003	34.65	40.5	19	1.607455023	37.2	1.57054294
20	2004	57.7	37.2	20	1.57054294	36.35	1.560504415
21	2005	34.7	36.35	21	1.560504415	35.95	1.555698895
22	2006	35	35.95	22	1.555698895	35.9	1.555094449
23	2007	60.1	35.9	23	1.555094449	35.65	1.552059534
24	2008	72.4	35.65	24	1.552059534	35	1.544068044
25	2009	31	35	25	1.544068044	34.8	1.541579244
26	2010	42.5	34.8	26	1.541579244	34.7	1.540329475
27	2011	47.2	34.7	27	1.540329475	34.65	1.539703239
28	2012	43.2	34.65	28	1.539703239	31	1.491361694
29	2013	179	31	29	1.491361694	29.6	1.471291711
30	2014	40.5	29.6	30	1.471291711	26.2	1.418301291
31	2015	51.4	26.2	31	1.418301291	24.8	1.394451681
32	2016	26.2	24.8	32	1.394451681		
	Sum		1644.55		53.46046384		52.85946922
	mean		51.3922		1.670639495		1.651858413
	Standard Deviation		28.2294		0.17492223		0.141258628
	Skewness coefficient(Cs)				0.002675043		0.288376628
	No of data(N)		32				

A: -Test for Higher outlier

For data N=32, K_n=2.591(from below the table for 1.2)

$\delta n-1$ =0.1749

Higher outlier YH=Y^{-}+$K_n\delta n-1$

YH=1.67706+2.596*0.1749=2.2138

Higher outlier=10^{YH}=132.9737

The highest recorded value from meteorological station is (179mm) is greater than the higher outlier (132.937mm). therefore, the highest value from record data. (179mm) will be exclude from hydrological analysis.

B: Lowe outlier test

YL=Y^{-}-$K_n\delta n-1$

YL=1.6706 -2.591*0.1749=1.2174

Lower outlier=10^{YL}=16.4981mm

The Lowest recorded value is (24.8mm) which is greater than lower outlier (16.4981mm). Hence no lower outlier date will have eliminated. Therefore, the recorded data is consistent for both outliers.

C: Checking Data Reliability

Number of data (N)=32

Standard Deviation ($\delta n-1$)=22.2294

Mean(X^{-})=51.3928

Standard error of mean ($\partial n-1$)= $\frac{28.2294}{\sqrt{32}}$=4.993

Relative Standard=$\frac{\partial n}{X-} * 100$=9.710%<10% hence the data series could be regarded as relabel and adequate.

D: **Precipitation Gauge Network**

The optimal number of rain gauge stations *N* required for a desired accuracy (or maximum error in per cent, ε) in the estimation of the mean rainfall.

The optimal number of rain gauge stations *N* is given as 4 station and Standard Deviation ($\delta n-1$)=16.22 , average depth of areal rainfall over a Bure catchment is 1465mm for 31 year.

$$N=(\frac{CV}{\varepsilon})^2$$

Here, Cv= the coefficient of variation of the rainfall values at the existing *m* stations (in percent)

and is Calculated as: $Cv = \frac{100*\delta n-1)}{X^-} = \frac{100*16.22}{1465.55}$ =1.11 =4= $(\frac{1.1}{\varepsilon})^2$ = $\mathcal{E}$=0.55<2%

Table 1.2: Outlier test kn value

simple size		simply size	Value	simple size	Value	simple size	Value
size N	Kn	N	Kn	N	Kn	N	Kn
10	2.036	24	2.467	38	2.661	60	2.837
11	2.088	25	2.467	39	2.671	65	2.866
12	2.134	26	2.502	40	2.682	70	2.893
13	2.175	27	2.519	41	2.692	75	2.917
14	2.213	28	2.534	42	2.7	80	2.94
15	2.247	29	2.549	43	2.71	85	2.917
16	2.309	30	2.563	44	2.719	90	2.961
17	2.309	31	2.577	45	2.727	95	2.981
18	2.361	32	2.591	46	2.736	100	3
19	2.385	33	2.604	47	2.744	110	3.017
20	2.408	34	2.619	48	2.744	120	3.078
21	2.408	35	2.628	49	2.753	130	3.107
22	2.429	36	2.639	50	2.76	140	3.214
23	2.448	37	2.65	55	2.768		

Table 1.3: Yearly Extreme Series and Frequency Analysis Calculations Gumbel Method

Design Point Rainfall							
Return Period	x⁻	$\delta n-1$	Yn	sn	YT	KT	X⁻+ $\partial n-1*KT$
2	47.276	16.22224	0.537	1.1159	0.36651292	-0.153	44.80
5					1.49993999	0.863	61.27
10					2.25036733	1.535	72.18
25					3.19853426	2.385	85.97
50					3.90193866	3.015	96.19
100					4.60014923	3.641	106.34

Table 1.4. Yearly Extreme Series and Frequency Analysis Calculations Log-Pearson Type IIII distribution

Return Period (T)	Design Point Rainfall				
	X−	$\boldsymbol{\delta}$n − 1	KT	YT=X+⁻KT*$\boldsymbol{\delta}n - 1$	XT=10^{YT}
2	1.6519	0.1413	-0.048028	1.65	44.16
5			0.824696	1.77	58.66
10			1.308072	1.84	68.65
25			1.845401	1.91	81.76
50			2.204968	1.96	91.90
100			2.535648	2.01	102.34

Table 1.5: Coefficient of skewness KT value for person type III distribution (positive skew)

Exceedance probability							
Return period in year		5	10	25	50	100	200
Skew coefficient Cs	0.5	0.2	0.1	0.04	0.02	0.01	0.005
3	-0.396	0.42	1.18	2.278	3.152	4.051	4.97
2.9	-0.39	0.44	1.195	2.277	3.134	4.013	4.909
2.8	-0.384	0.46	1.21	2.2275	3.114	3.973	4.847
2.7	-0.376	0.479	1.224	2.272	3.093	3.932	4.783
2.6	-0.368	0.499	1.238	2.262	3.071	3.889	4.718
2.5	-0.36	0.518	1.25	2.256	3.048	3.845	4.652
2.4	-0.351	0.537	1.262	2.248	3.023	3.8	4.584
2.3	-0.341	0.555	1.274	2.24	2.997	3.753	4.515
2.2	-0.33	0.574	1.284	2.23	2.97	3.705	4.444
2.1	-0.319	0.592	1.294	2.219	2.942	3.656	4.372
2	-0.307	0.609	1.302	2.207	2.912	3.605	4.298
1.9	-0.294	0.627	1.31	2.193	2.881	3.553	4.223
1.8	-0.282	0.643	1.318	2.179	2.848	3.499	4.147
1.7	0.2268	0.66	1.324	2.163	2.815	3.444	4.069
1.6	-0.254	0.675	1.329	2.146	2.78	3.388	3.99
1.5	-0.24	0.69	1.33	2.128	2.743	3.33	3.91
1.4	-0.225	0.705	1.337	2.108	2.706	3.271	3.829
1.3	-0.21	0.719	1.339	2.087	2.666	3.211	3.745
1.2	-0.195	0.732	1.339	2.066	2.626	3.149	3.661
1.1	-0.18	0.745	1.336	2.043	2.585	3.087	3.575
1	-164	0.758	1.34	2.018	2.492	3.022	3.489
0.9	-0.148	0.769	1.339	1.993	2.453	3.022	3.401
0.8	-0.132	0.78	1.336	1.967	2.407	2.957	2.949
0.7	-0.166	0.79	1.33	1.939	2.359	2.891	2.856
0.6	-0.099	0.8	1.328	1.91	2.311	2.824	2.763
0.5	-0.083	0.808	1.323	1.88	2.261	2.755	2.67
0.4	-0.066	0.816	1.317	1.849	2.211	2.686	2.61
0.3	-0.05	0.824	1.309	1.818	2.159	2.615	2.51
0.2	-0.033	0.83	1.301	1.785	2.107	2.544	2.48
0.1	-0.017	0.836	1.292	1.751	2.054	2.472	2.403
0	0	0.842	1.282	1.742	2.001	2.4	2.3

Sourcs (Vente Chow, 1998)

Using the above Methodology formula, the following rainfall ratio (RRt) for different minutes of durations computed in Table 1.6 equations from 3.10

Table 1.6: Rainfall ratio (RRt) computation sheet

t(mint)	5	10	15	20	30	60	90	120	130	140	160	180
t(hr)	0.08	0.17	0.25	0.33	0.50	1.00	1.50	2.00	2.17	2.33	2.67	3.00
b+24	24.30	24.30	24.30	24.30	24.30	24.30	24.30	24.30	24.30	24.30	24.30	24.30
$(b+24)^n$	17.66	17.66	17.66	17.66	17.66	17.66	17.66	17.66	17.66	17.66	17.66	17.66
b+t	0.38	0.47	0.55	0.63	0.80	1.30	1.80	2.30	2.47	2.63	2.97	3.30
$(b+t)^n$	0.42	0.50	0.58	0.66	0.82	1.27	1.70	2.12	2.25	2.34	2.66	2.93
RRt	0.14	0.24	0.32	0.37	0.45	0.58	0.65	0.69	0.71	0.73	0.74	0.75

Then using the correlation (Rt=RRt*R24), for each years of record of 24hr rainfall(mm) result changed to 5,10,15,20,30,60,90,120,130,140,160 and 180 minutes' rainfall results

Table 1.7. Rainfall of shorter duration for Bure town using log person III for n=0.92, b=0.3

Duration(mint)	T year=	2	5	10	25	50	100.0
	R24 =	44.2	58.7	68.7	81.8	91.9	102.3
5		77.0	102.3	119.7	142.6	160.3	178.5
10		64.5	85.7	100.3	119.5	134.3	149.5
15		55.7	73.9	86.5	103.1	115.8	129.0
20		49.0	65.1	76.2	90.8	102.0	113.6
30		39.7	52.8	61.8	73.6	82.7	92.1
60		25.7	34.1	39.9	47.5	53.4	59.5
90		19.1	25.4	29.8	35.5	39.8	44.4
120		15.4	20.4	23.9	28.4	32.0	35.6
130		14.4	19.1	22.4	26.7	30.0	33.4
140		13.9	18.4	21.6	25.7	28.9	32.1
160		12.2	16.2	19.0	22.6	25.4	28.3
180		11.1	14.7	17.3	20.5	23.1	25.7

Appendices 2:24hr Rainfall Depth Vs Frequency Rainfall for classified Region A2 for IDF Curve development ((ERA, 2013) **.**

Table 2.1 Meteorology station in Ethiopia (Years of record through 2010)

Meteorological Region	Station	Years of Record	Meteorological Region	Station	Years of Record
A1	Axum	17	B	Bedele	39
	Mekele	46		Gore	56
	Maychew	32		Nekempte	40
A2	Gondar	52		Jima	54
	Debre Tabor	15		Arba Minch	23
	Bahir Dar	45		Sodo	49
	Deber Markos	55		Awasa	36
	Fitche	44	C	Kombolcha	57
	Addis Ababa	57		Woldiya	29
	Debre Zeit	55		Sirinka	27
A3	Nazareth	46	D1	Gode	33
	Kulums	43		Kebre Dihar	40
	Robe/Bale	29	D2	Kibre Mengist	33
A4	Metehara	24		Negele	51
	Dire Dawa	58		Moyale	29
	Mieso	42		Yabelo	34

Table 2.2 Rainfall of shorter duration using log-Pearson III

24 rainfall Depth(mm)Vs Frequency(year)								
Return Period Year	2	5	10	25	50	100	200	500
RR-A1	50.3	66.02	76.28	89.13	98.63	108.06	117.48	130
RR-A2	51.92	65.52	74.45	85.7	94.07	102.45	110.91	122.27
RR-A3	47.54	59.62	67.66	77.92	85.62	93.34	101.13	111.58
RR-A4	50.39	63.83	72.28	82.55	89.97	97.2	104.32	113.63
RR-B1	58.87	71.26	79.29	89.35	96.84	104.37	112.02	122.41
RR-B2	55.26	69.95	79.68	92.03	101.29	110.61	120.07	132.87
RR-C	55.26	71.04	80.54	92.52	101.29	110.5	119.66	132.06
RR-D	56.23	76.84	90.37	107.46	120.23	133.05	146	163.44
Note: RR-Rainfall Regions								

Source: (ERA, 2013)

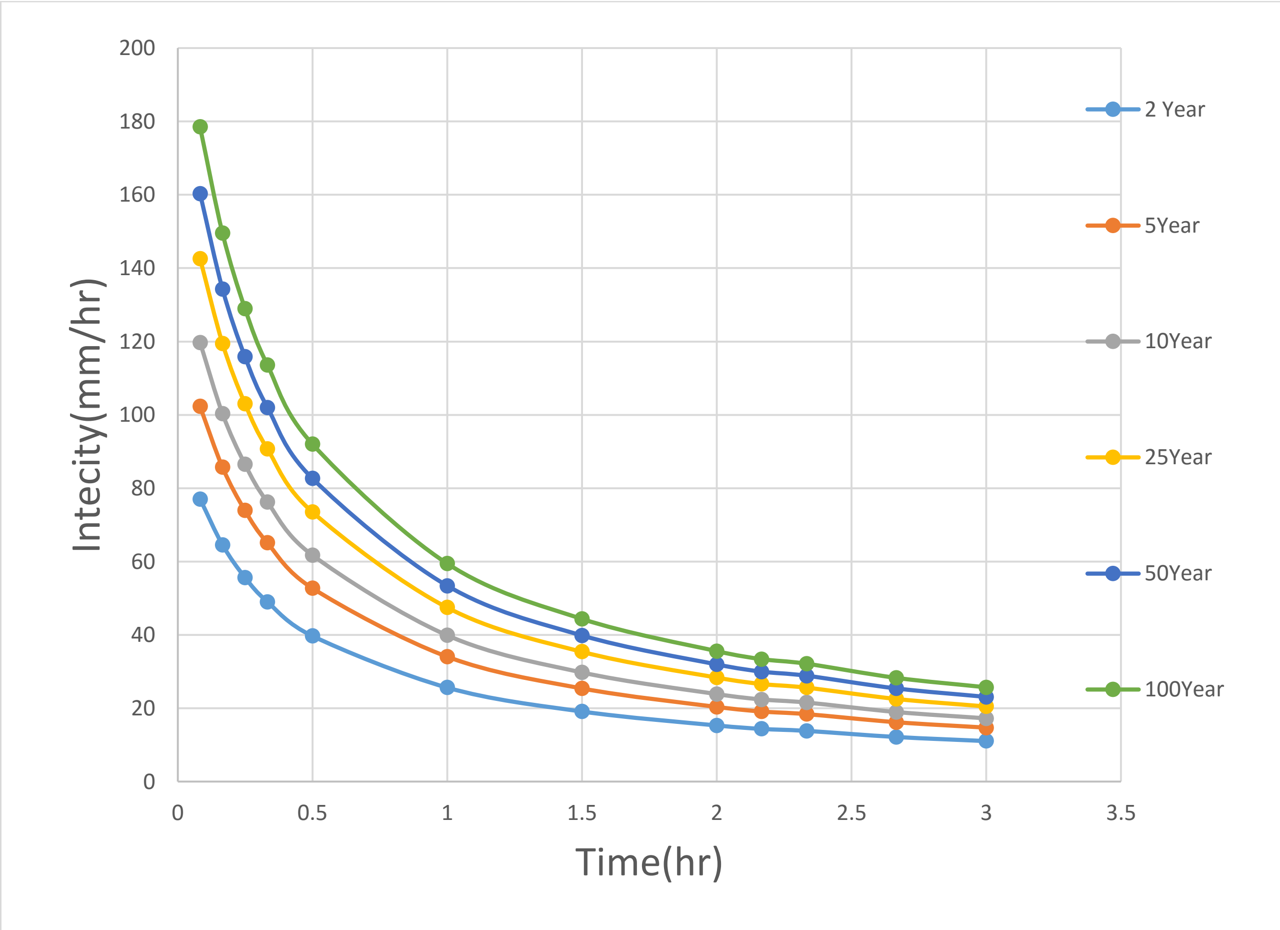

Figure 2.1: IDF Curve of Rainfall Region A2

Appendices 3: Peak discharge Estimation for Bure town catchment using rational method.

Time of concentration

The sheet flow occurs up to 100 meters, Short grass slope of 0.04 m/m, CM-1, but other is estimated in estimated in below Natural Manning Coefficient=0.14, P2= 2-year for 24 hr. rainfall= 44.1mm, L=100m and slop(S1) = 0.013 in CM-1, Hence, from Equation (3.14), travel time for sheet flow is determined as:

$Tt=[0.091(nL)^{0.8}/(P2)^{0.5}S^{0.4}]$

Tt1 **(Sheet Flow Time)** = **0.6378hr**

For shallow concentrated flow, unpaved watershed slope is approximated S1=0.01 and length from topography map is 768.28m Using equation (3.51b), $V=4.9178(S)^{0.5}$ for unpaved watershed. $V=4.9178(0.01)^{0.5}$ = 0. 56m/sec and from equation (3.15). Finally, from equation (3.51), travel-time is determined as: The estimation of shallow concentrated flow (Time of concertation Tt2) for given catchment Unpaved watershed. the slop of CM-1 is and the other catchment is estimated in appendix.

Tt2= 0.38hr

For channel flow, natural stream channel, winding with weeds and pools, slope is 0.013m/m, and length is 768. 28m.Rectangulr channel for cachement-1 (CM-1): 1V:1H, width(w1) =1.3, depth(d1) =0.5, s1=0.01, Manning's n channel (n=0.04), Area of channel(A1) =1.15m^2, perimeter of channel=2.714m and v channel= 1m/s

Tt3= 0.231hr

The time of concentration is the sum of Tt values for the various consecutive flow segments:

Tc=Tt1+Tt2+Tt3 =0.6378hr+0.38+0.231hr=1.2488hr

Tc=Where: Tc = time of concentration, hr.= number of flow segment

Table 3.1. Time of concentration result in drainage system

Sub catchment No	Depth m	width m	slope %	Length of Drainage m	Sheet Flow TC1(hr)	Shallow Concentrated Flow TC2(hr)	Open Channels Flow TC3(hr)	Total Tc (hr)
CM-1	0.5	1.3	0.01	768.28	0.6378	0.38	0.231	1.2488
CM-2	0.4	1.25	0.01	690	0.61	0.314	0.148	1.072
CM-3	0.6	1.3	0.01	920.05	0.685	0.5	0.187	1.372
CM-4	0.4	0.6	0.01	857.19	0.66531	0.45	0.231	1.34631
CM-5	0.45	0.7	0.01	933.741	0.689	0	0	0.689
CM-6	0.5	0.6	0.02	656.25	0.599	0.3	0.146	1.045
CM-7	0.45	0.6	0.01	729.14	0.624	0	0	0.624
CM-8	0.6	0.9	0.03	334.51	0.456	0	0	0.456
CM-9	0.3	0.7	0.04	268.06	0.418	0.07	0.046	0.534
CM-10	0.3	0.5	0.01	855.35	0.286	0	0	0.286
CM-11	0.4	0.7	0.01	1039.05	0.708	0	0	0.708
CM-12	0.5	1.3	0.02	989.07	0.55	0	0	0.55
CM-13	0.65	1.21	0.02	539.85	0.553	0.22	0.08	0.853
CM-14	0.5	0.9	0.01	971.59	0.702	0.54	0.24	1.482

Table 3.2: Runoff coefficient based on hydrologic soil group (ERA, 2013)

Terrain Type	Soil type			
	A	B	C	D
Flat<2%	0.04 to0.09	0.07 to 0.12	0.11 to0.16	0.15 to 0.20
Rolling 2% to 6%	0.09 to 0.14	0.12 to 0.17	0.16 to 0.21	0.20 to 0.25
Mountainous 6% to 15%	0.13 to0.18	0.18 to0.24	0.23 to0.31	0.28 to 0.38
Escarpment> 15%	0.18 to0.22	0.24 to 0.30	0.3 to0.4	0.38 to 0.48

Table 3.3: Runoff Coefficient for Use in Rational Method Source: (ERA, 2013).

Type of Drainage Area	Runoff Coefficient (C)
Business:	
Downtown areas	0.70 - 0.95
Neighborhood areas	0.50 - 0.70
Residential:	
Single-family areas	0.30 - 0.50
Multi-units, detached	0.40 - 0.60
Multi-units, attached	0.60 - 0.75
Suburban	0.25 - 0.40
Apartment dwelling areas	0.50 - 0.70
Industrial:	
Light areas	0.50 - 0.80
Heavy areas	0.60 - 0.90
Parks, cemeteries	0.10 - 0.25
Playgrounds	0.20 - 0.40
Railroad yard areas	0.20 - 0.40
Unimproved areas	0.10 - 0.30
Lawns:	
Sandy soil, flat, 2%	0.05 - 0.10
Sandy soil, average, 2 - 7%	0.10 - 0.15
Sandy soil, steep, 7%	0.15 - 0.20
Heavy soil, flat, 2%	0.13 - 0.17
Heavy soil, average, 2 - 7%	0.18 - 0.22
Heavy soil, steep, 7%	0.25 - 0.35
Streets:	
Asphaltic	0.70 - 0.95
Concrete	0.80 - 0.95
Brick	0.70 - 0.85
Drives and walks	0.75 - 0.85
Roofs	0.75 - 0.95

Higher values are usually appropriate for steeply sloped areas and longer return periods because infiltration and other losses have a proportionally smaller effect on runoff in these cases (ERA, 2013).

Table 3-5. Typical Range of Manning's Coefficient (n) for Channels and Pipes (FHWA, 2014).

Conduit Material	Manning's n*
Closed Conduits	
Concrete pipe	0.010 - 0.015
CMP	0.011 - 0.037
Plastic pipe (smooth)	0.009 - 0.015
Plastic pipe (corrugated)	0.018 - 0.025
Pavement/gutter sections	0.012 - 0.016
Small Open Channels	
Concrete	0.011 - 0.015
Rubble or riprap	0.020 - 0.035
Vegetation	0.020 - 0.150
Bare Soil	0.016 - 0.025
Rock Cut	0.025 - 0.045
Natural channels (minor streams, top width at flood stage <30 m (100 ft))	
Fairly regular section	0.025 - 0.050
Irregular section with pools	0.040 - 0.150

Table 3.6 : Table of acceptable pipe Grade for pipes flowing((AACRA, 2003)

Pipe Diameter(mm)	Maxmime.Grade (%)	Minmume.Grad(%)
300	20	0.5
375	15	0.4
450	11	0.3
525	9	0.25
600	7.5	0.2
675	6.5	0.18
750	5.5	0.15
900	4.5	0.12
1050	3.5	0.1
1200	3	0.1
1350	2.5	0.1
1500	2.2	0.1
1650	2	0.1
1800	1.7	0.1
1950	1.5	0.1

Appendices 4: Storm water drainage diameter fixing for current condition of drainage.

A: Storm water drainage diameter fixing for current condition drainage for catchment one. The other storm water drainage size for each catchment is estimated by the same procedure and presented in below the table.

$Q= \frac{AR^{2/3}s^{0.5}}{n}$(manning equation)

$A_{circle}=\frac{\pi}{4}D^2$,P=ΠD and $RC_{ircle}=\frac{D}{4}$ (π=3.14)

$Q= \frac{\pi D^2 D^{2/3} 0.01^{0.5}}{4*0.02}=$ (rational method – current condition) Discharged

$\frac{\pi D^2 D^{2/3} 0.01^{0.5}}{4*0.02}=2.38-1.84$

$\frac{\pi D^2 D^{2/3} 0.01^{0.5}}{4*0.02}=0.54$

D=0.3772m=377mm. This means that the rectangular channel not the capacity to carry in catchment out flow and redesign

Table 4. 1: The diameter of to be existing drainage mentioned values for each sub-catchment.

Sub -catchment	(Rational method - current condition) discharge	Diameter(m)
CM-1	0.54	0.451
CM-2	0.58	0.122
CM-3	0.36	0.344
CM-4	0.01	0.002
CM-5	2.98	1.036
CM-6	1.88	0.681
CM-7	0.48	0.393
CM-8	3.18	0.327
CM-9	3.50	0.656
CM-10	7.09	1.291
CM-11	3.11	1.130
CM-12	2.47	0.278
CM-13	0.25	0.269
CM-14	1.48	0.746

Appendices 5: Storm water drainage diameter fixing for current condition of drainage using Rational method.

The other storm water drainage size for each catchment is estimated by the same procedure and presented in the table below.

Q= $\frac{AR^{2/3}s^{0.5}}{n}$(manning equation)

Q= $\frac{\pi D^2 D^{2/3} 0.01^{0.5}}{4*0.02}$= (CM-1 discharge for rational)

$\frac{3.14*D^2 D^{2/3} 0.01^{0.5}}{4*0.02}$=2.38

D=0.789m=789mm

The other storm water drainage size for each catchment is estimated by the same procedure and presented in below the table 5.1.

Table 5. 1: The diameter of to be Rational method mentioned values for each sub-catchment,

Sub -catchment	Rational method discharge	Dimeter(m)	Diameter(mm)
CM-1	2.38	0.789	789
CM-2	2.77	0.818	818
CM-3	3.17	0.778	778
CM-4	2.2	0.665	665
CM-5	4.24	1.183	1183
CM-6	3.4	1.081	1081
CM-7	2.97	0.781	781
CM-8	6.54	0.862	862
CM-9	5.63	0.784	784
CM-10	7.99	1.151	1151
CM-11	3.92	1.233	1233
CM-12	4.99	0.805	805
CM-13	3.89	0.756	756
CM-14	2.8	1.138	1138

Table 5.2: Access Hole Sizing

Manhole	maximum pipe size (mm)
675	375
1050	675
1200	750
1350	900
1500	1050
1650	1200
1800	1350
1950	1500
2100	1650
2250	1800
2400	1800
2550	1950
2700	2100

(City Waters Unit Manager, 2010)

Appendix 6: Manholes Summery

Table 6.1. Manholes Drainage System Result

ID	Label	Elevation ground (m)	Length (m)	Diameter (mm)	velocity (m/s)	Flow (Total Out) (m^3/s)	Volume (m^3)	Outfall Catchment
51	MH-1	1,960.26	100	675.00	1.785	5.27	78.5	O-1
52	MH-2	1,962.68	100	375.00	1.785	2.48	63.6	O-1
53	MH-3	1,968.54	100	375.00	1.785	2.48	76.1	O-1
54	MH-4	1,987.76	100	375.00	1.785	2.48	82.7	O-1
55	MH-5	1,960.26	100	375.00	1.975	**2.5**	0.5	O-1
56	MH-6	1,962.68	100	375.00	1.975	**2.52**	429.6	O-1
57	MH-7	1,989.73	100	750.00	1.944	3.85	313.6	O-4
58	MH-8	1,987.76	100	750.00	1.944	3.85	291.4	O-4
59	MH-19	1,994.28	100	750.00	1.944	3.85	282.5	O-4
60	MH-10	1,997.84	100	750.00	1.944	3.85	255.3	O-4
61	MH-11	2,005.37	100	750.00	1.944	3.85	241.1	O-4
62	MH-12	1,960.06	100	750.00	1.944	3.85	225.4	O-4
63	MH-13	1,970.00	100	375.00	1.756	6.38	202.1	O-4
64	MH-14	1,979.79	100	750.00	1.756	4.4	94.4	O-2
65	MH-15	1,980.00	100	375.00	1.756	2.31	100.8	O-2
67	MH-16	2,006.37	100	375.00	1.756	2.31	116.3	O-2
68	MH-17	2,001.56	100	375.00	1.756	2.31	122.8	O-2
69	MH-18	2,004.01	100	375.00	1.756	2.31	130	O-2
71	MH-19	1,997.69	100	375.00	5.614	2.31	265.5	O-5
72	MH-20	1,955.94	100	375.00	2.234	4.55	265.5	O-5
73	MH-21	1,965.62	100	375.00	2.234	4.55	237.4	O-5
74	MH-22	2,001.00	100	375.00	2.234	4.55	208.8	O-5
77	MH-23	1,967.87	100	375.00	2.234	4.55	182.5	O-5
78	MH-24	1,968.12	100	675.00	4.876	**14.03**	430.8	O-3
79	MH-25	2,001.39	100	375.00	2.234	**14.58**	438.1	O-3
80	MH-26	1,961.07	100	375.00	2.234	**14.58**	429.3	O-3
82	MH-27	1,958.27	100	375.00	2.234	4.55	155.8	O-5
84	MH-28	1,960.00	100	375.00	2.739	**5.41**	429	O-3

Continue table 6.1. Manholes Drainage System Result

85	MH-29	1,951.05	100	375.00	2.739	**5.41**	427.1	O-3
86	MH-30	1,953.86	100	750.00	1.984	**5.41**	427.7	O-3
87	MH-31	1,952.34	100	750.00	1.8456	**11.68**	427.4	O-3
88	MH-32	1,949.35	100	750.00	1.7976	**5.75**	426.7	O-3
89	MH-33	1,968.54	100	750.00	5.614	5.75	427.1	O-3
91	MH-34	1,970.00	100	375.00	1.715	2.48	70.1	O-1
95	MH-35	1,980.00	100	375.00	3.894	**2.52**	433.4	O-1
97	MH-36	1,980.21	100	675.00	1.745	6.66	134.9	O-5
99	MH-37	1,946.97	100	675.00	3.742	**4.25**	426.2	O-3
100	MH-38	1,940.91	100	375.00	1.662	2.31	136.4	O-2
107	MH-39	1,961.35	100	675.00	5.614	2.31	426.2	O-3
108	MH-40	1,964.51	100	675.00	5.614	2.31	424.1	O-3
113	MH-41	1,966.00	100	375.00	1.856	2.31	108.8	O-2
117	MH-42	2,001.39	100	375.00	2.345	**14.58**	438.1	O-3
118	MH-43	1,968.54	100	750.00	2.746	**2.96**	430.9	O-3
119	MH-44	1,937.21	100	675.00	2.891	**5.91**	424.1	O-3
120	MH-45	1,975.00	100	675.00	5.614	5.91	424.1	O-3
130	MH-46	1,987.21	100	375.00	1.784	**11.68**	21.4	O-3
131	MH-47	1,949.35	100	375.00	1.975	**11.68**	41.5	O-3
132	MH-48	1,945.14	100	375.00	5.614	4.4	14.8	O-5
133	MH-49	2,001.39	100	375.00	5.614	4.4	208.8	O-5
134	MH-50	2,001.39	100	375.00	5.614	4.4	116.3	O-2
135	MH-51	1,952.34	100	375.00	5.614	4.4	116.3	O-2
136	MH-52	1,952.34	100	375.00	5.614	4.4	255.3	O-4
137	MH-53	1,967.87	100	375.00	5.614	4.4	255.3	O-4
138	MH-54	1,967.87	100	750.00	5.614	4.4	76.1	O-1
139	MH-55	1,980.00	100	750.00	5.614	4.4	76.1	O-1
140	MH-56	1,980.00	100	750.00	1.662	4.4	14	O-2
141	MH-57	1,987.76	100	750.00	1.662	4.4	29	O-2
143	MH-58	1,987.76	100	675.00	2.34	**14.03**	435.1	O-3
144	MH-59	1,946.00	100	675.00	2.34	**14.03**	426	O-3

Continue table 6.1. Manholes Drainage System Result

145	MH-60	1,930.00	100	675.00	1.653	6.66	63.1	O-5
146	MH-61	1,950.00	100	375.00	5.614	6.66	99.9	O-1
147	MH-62	1,945.00	100	375.00	1.765	6.38	165.9	O-4
148	MH-63	1,920.00	100	375.00	1.986	6.38	56.5	O-4

Appendix 7: conduit Summery

Table 7.1: Conduit Drainage System Result

ID	Label	Start Node	Stop Node	Flow (m^3/s)	Manning's n	Diameter(mm)	slope(%)	length(m)	Outfall Drain
149	CO-1	MH-2	MH-1	2.48	0.013	375	0.5	100	O-1
151	CO-2	MH-2	MH-34	2.48	0.013	375	0.5	100	O-1
152	CO-3	MH-34	MH-3	2.48	0.013	375	0.5	100	O-1
153	CO-4	MH-3	MH-4	2.48	0.013	375	0.5	100	O-1
154	CO-5	MH-4	MH-5	2.5	0.013	525	0.25	100	O-1
155	CO-6	MH-5	MH-35	2.52	0.013	525	0.25	100	O-1
156	CO-7	MH-35	MH-6	2.52	0.013	525	0.25	100	O-1
157	CO-9	MH-7	MH-8	3.85	0.013	375	0.5	100	O-4
158	CO-10	MH-8	MH-19	3.85	0.013	375	0.5	100	O-4
159	CO-11	MH-19	MH-10	3.85	0.013	375	0.5	100	O-4
160	CO-12	MH-10	MH-11	3.85	0.013	375	0.5	100	O-4
161	CO-13	MH-11	MH-12	3.85	0.013	375	0.5	100	O-4
162	CO-14	MH-12	MH-13	3.85	0.013	375	0.5	100	O-4
163	CO-16	MH-14	MH-15	2.31	0.013	375	0.5	100	O-2
164	CO-17	MH-15	MH-41	2.31	0.013	375	0.5	100	O-2
165	CO-18	MH-41	MH-16	2.31	0.013	375	0.5	100	O-2
166	CO-19	MH-16	MH-17	2.31	0.013	375	0.5	100	O-2
167	CO-20	MH-17	MH-18	2.31	0.013	375	0.5	100	O-2
168	CO-21	MH-18	MH-38	2.31	0.013	375	0.5	100	O-2
169	CO-23	MH-19	MH-20	2.31	0.013	375	0.5	100	O-5
170	CO-24	MH-20	MH-21	4.55	0.013	375	0.5	100	O-5

Continue table 7.1. Conduit Drainage System Result

171	CO-25	MH-21	MH-22	4.55	0.013	375	0.5	100	O-5
172	CO-26	MH-22	MH-23	4.55	0.013	375	0.5	100	O-5
173	CO-27	MH-23	MH-27	4.55	0.013	375	0.5	100	O-5
174	CO-28	MH-27	MH-36	4.55	0.013	375	0.5	100	O-5
175	CO-30	MH-24	MH-25	14.58	0.013	675	0.2	100	O-3
176	CO-31	MH-25	MH-26	14.58	0.013	675	0.2	100	O-3
177	CO-32	MH-26	MH-42	14.58	0.013	675	0.2	100	O-3
178	CO-33	MH-42	MH-28	5.41	0.013	450	0.2	100	O-3
179	CO-34	MH-28	MH-29	5.41	0.013	450	0.3	100	O-3
180	CO-35	MH-29	MH-33	2.79	0.013	450	0.3	100	O-3
181	CO-37	MH-30	MH-43	2.96	0.013	375	0.5	100	O-3
182	CO-38	MH-43	MH-32	2.96	0.013	375	0.5	100	O-3
183	CO-39	MH-32	MH-31	5.75	0.013	450	0.3	100	O-3
184	CO-40	MH-31	MH-44	5.91	0.013	450	0.3	100	O-3
185	CO-41	MH-44	MH-45	5.641	0.013	450	0.3	100	O-3
186	CO-42	MH-45	MH-40	5.641	0.013	450	0.3	100	O-3
229	CO-44	MH-39	MH-37	5.641	0.013	450	0.3	100	O-3
230	CO-45	MH-37	MH-31	4.25	0.013	375	0.3	100	O-3
231	CO-46	MH-46	MH-47	11.68	0.013	675	0.18	100	O-3
232	CO-47	MH-47	MH-42	11.68	0.013	675	0.18	100	O-3
233	CO-48	MH-48	MH-49	5.641	0.013	375	0.5	100	O-5
234	CO-49	MH-49	MH-22	5.641	0.013	375	0.5	100	O-5
235	CO-50	MH-50	MH-51	5.641	0.013	375	0.5	100	O-2
236	CO-51	MH-51	MH-16	5.641	0.013	375	0.5	100	O-2
237	CO-52	MH-52	MH-53	5.641	0.013	375	0.5	100	O-4
238	CO-53	MH-53	MH-10	5.641	0.013	375	0.5	100	O-4
239	CO-54	MH-54	MH-55	5.641	0.013	375	0.5	100	O-1
240	CO-55	MH-55	MH-3	5.641	0.013	375	0.5	100	O-1
241	CO-61	MH-61	MH-3	5.641	0.013	375	0.5	100	O-1
249	CO-56	MH-14	MH-56	4.4	0.013	375	0.5	100	O-2
250	CO-57	MH-56	MH-57	4.4	0.013	375	0.5	100	O-2

Continue table 7.1. Conduit Drainage System Result

252	CO-65	MH-57	O-2	4.4	0.013	375	0.5	100	O-2
254	CO-58	MH-24	MH-58	14.03	0.013	675	0.2	100	O-3
255	CO-59	MH-58	MH-59	14.03	0.013	675	0.2	100	O-3
256	CO-64	MH-59	O-3	14.03	0.013	675	0.2	100	O-3
258	CO-15	MH-13	MH-62	6.38	0.013	450	0.2	100	O-4
259	CO-62	MH-62	MH-63	6.38	0.013	450	0.2	100	O-4
260	CO-63	MH-63	O-4	6.38	0.013	450	0.2	100	O-4
261	CO-29	MH-36	MH-60	6.66	0.013	450	0.2	100	O-5
262	CO-60	MH-60	O-5	6.66	0.013	450	0.2	100	O-5
264	CO-66	MH-1	O-1	5.27	0.013	450	0.2	100	O-1
267	CO-67	MH-46	MH-31	11.68	0.013	675	0.2	100	O-3

Appendix 9: Outfall Summery

Table 4.5.4. Outfall Drainage System Result

ID	Label	Elevation (Ground) (m)	Flow (Total Out) (m^3/s)
125	O-2	1,920.00	4.4
126	O-3	1,940.00	14.03
127	O-5	1,935.00	6.66
128	O-4	1,960.00	6.38
263	O-1	1,959.50	5.27

Appendix 10: Accuracy assessment of land use land cover map data for Landsat satellite

Kappa Cofficiante1986=

$$\frac{113*(6+21+25+24+18)-\sum(10*6+23*27+30*30+27*28+27*22)}{113^2-\sum(10*6+23*27+30*30+27*28+27*22)}$$

=0.781= 78.1%

The same step to estimate accuracy assessment land use and land cover satellite data 2010 and 2017 are 85% and 86% respectively.

Table 10.1.:Accuracy assessment land use land cover in 1986

References from ground truth							
User image 1986 classified	Lulc of the town	Built up area	Agricultural	Vegetation	Bear land	Water Body	Total
	Built-up Area	6	2	1	0	1	10
	Agricultural	0	21	1	1	0	23
	Vegetation	0	1	25	2	2	30
	Baer Land	0	1	1	24	1	27
	Water Body	0	2	2	1	18	23
	Total	6	27	30	28	22	113

Table 10.2. Accuracy assessment land use land cover in 2010

References from ground truth							
User image 2010 classified	Lulc of the town	Built up area	Agricultural	Vegetation	Bear land	Water Body	Total
	Built -up Area	10	2	1	0	1	14
	Agricultural	0	30	1	1	0	32
	Vegetation	0	1	40	2	2	45
	Baer Land	0	1	1	30	1	33
	Water Body	0	2	2	1	25	30
	Total	10	36	45	34	29	154

Table 10.3. Accuracy assessment land use land cover in 2017

References from ground truth							
User image 2017 classified	Lulc of the town	Built up area	Agricultural	Vegetation	Bear land	Water Body	Total
	Built -up Area	40	2	1	0	1	44
	Agricultural	0	35	1	1	0	37
	Vegetation	1	1	36	2	2	42
	Baer Land	0	2	0	30	0	32
	Water Body	2	2	2	1	25	32
	Total	43	42	40	34	28	187

Appendices 11: Challenges of Storm Water Drainage managements in the Study Area

Annex I: Interview Question for the Bure town community

A: General Information

Name of informer------------------Sex------------Age---------- Education Background-------

Position------------

B. Specific Storm Water Drainage Related Questions:

1. Does Urban flooding one of the major challenges in Bure town?

   A. Yes
   B. No

2. If your answer is yes, how do you rate the extent?

   A. Very high
   B. High
   C. Medium
   D. Low
   E. limited
   F. Other__________________________________

3.What do you think is the possible cause of the stormwater drainage system is not? control?

   A. Heavy Rain
   B. Sediment is occupied
   C. Heavy load
   D. Lack of drainage
   E. Other____

4.What do you think is the major causes of flooding problem in your Town?

   A. Absence of urban storm water drainage infrastructure
   B. Inadequate urban storm water drainage infrastructure
   C. Blockage of urban storm water drainage structures
   D. If others specify_____________________________________

5.How do you judge the construction quality of the constructed storm water drainage system and Status of Existing Drainage System of the town (Poor, fair, good, very good, Excellent)

6.If your response for question number 5 is poor, what construction shortage have you observed on the constructed storm water drainage system?

7.What are the reasons of the area to dispose solid wastes in to the stormwater drainage systems?

A. Lack of awareness
B. Shortage of disposing area
C. Carelessness
D. Others, Explain

8.Which one the major challenges of urban storm water drainage system in Bure Town?

A. Natural Drainage Problems
B. Human activity-related Problems
C. Others specify ____________________

9. Which specific sites are most prone to flooding for town and why?

10.What temporary solutions/measures have ever been taken to the urban flooding problems?

11.What solutions you suggest to handle such flooding problems on existing stormwater drainage system?

12.How the stormwater management problems minimized and what measures are?

13.What do you think should be done to have Stormwater drainage problem for the future?

14.What role is set for the community in the expansion of stormwater drainage systems?

15.What reasons you believe are accounted for the unsustainably use of the urban stormwater drainage facilities in the area?

16.What supports did the community get from the Government organizations in relation to managing the stormwater drainage system to make properly functional and sustainable?

17.Generally any comments/suggestion regarding in management the impact of the urban drainage system on Bure town_________________________

Thank you!!!